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Final

**ROUND TWO
REMEDIAL INVESTIGATION REPORT
SITES 4, 21, and 22**

**NAVAL WEAPONS STATION YORKTOWN
YORKTOWN, VIRGINIA**

VOLUME I - TEXT

CONTRACT TASK ORDER 0349

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EXECUTIVE SUMMARY

This report presents the results of the Round Two Remedial Investigation (RI) completed for Sites 4 (Burning Pad Residue Landfill), 21 (Battery and Drum Disposal), and 22 (Burn Pad) at the U.S. Naval Weapons Station Yorktown (WPNSTA Yorktown), Yorktown, Virginia. This RI Report has been prepared by Baker Environmental, Inc. (Baker) under the Department of the Navy's (DoN's) Comprehensive Long-Term Environmental Action Navy (CLEAN) contract administered by the Naval Facilities Engineering Command, Atlantic Division (LANTDIV).

The objectives of this report are: (1) to evaluate the results of the Round One and Round Two RI efforts and the Removal Action confirmation sampling conducted at Sites 4 and 21; (2) to assess the nature and extent of contamination at the sites and/or to identify data gaps preventing an adequate understanding of site conditions; and (3) to assess potential human health and ecological risks associated with any contamination remaining at the sites following the removal actions.

SITES 4, 21, and 22-DESCRIPTION AND HISTORY

Site 4 - Burning Pad Residue Landfill

Site 4, the Burning Pad Residue Landfill, consists of over 10 acres. The site is bordered by the Explosives Burning Facility 1401 (Site 22) to the southwest, Site 21 (the Battery and Drum Disposal Area) and an unnamed drainage way to the southeast, West Road to the northeast, and a gravel road leading to the burning facility to the northwest.

The use of Site 4 as a disposal area began in 1940 and ended in approximately 1975. Reportedly, the landfill was a ravine in which trench and fill operations took place. The landfill area was reportedly backfilled three to four times a week (C.C. Johnson, 1984). An ash pile measuring approximately 100 feet by 150 feet was located in the northeast corner of the site.

Materials reportedly disposed at Site 4 included: carbon-zinc batteries from underwater weapons; burning pad residues (possibly containing aluminum, cyclotrimethylene trinitroamine [RDX], TNT, 2,4-dinitrotoluene [2,4-DNT], and cyclotetramethylenetetranitramine [HMX]); tree stumps; fly ash from coal-fired boilers; mine casings; electrical equipment (possibly telephone poles, line

hardware, etc.); and transformers (possibly containing polychlorinated biphenyl [PCB] oils). The landfill received an estimated 17 tons of waste per year (C.C. Johnson, 1984). The depth of fill in the main fill area was estimated from a geophysical study to be approximately 5 to 10 feet.

An investigation of subsurface source areas, conducted by IT Corporation (IT) in December 1992, identified a large battery disposal area located in the southeast part of the site. The batteries were found between 2 and 4 feet below ground surface (bgs). Additional landfill material consisting of construction debris, scrap metal, piping, glass, concrete, bottles, cans, and drums, was also identified at various locations within the site boundary.

In 1994, IT conducted a Removal Action at the site to dispose of the surface debris and the battery disposal areas. Materials were removed from several areas throughout the site. One of these areas included the area around an ash pile located in the northeast corner of the site near West Road.

The majority of the site is relatively open, with scrub grasses and small trees; larger trees are present in the northern and southeastern portions of the site. A gravel road now loops through the site and meets West Road. A dirt or gravel road formerly cut through the site and led towards Site 22. The topography within the open area of Site 4 is relatively flat with elevations ranging between 33 to 47 feet above mean sea level (msl). In the wooded areas along the southeastern portion of the site, the topography slopes sharply down towards the unnamed drainage way with elevations changing from 39 to less than 10 feet above msl.

Site 21 - Battery and Drum Disposal Area

Site 21, the Battery and Drum Disposal Area, is a small wooded area covering approximately 1-acre. The site is located immediately adjacent to the unnamed drainage way leading to Felgates Creek. West Road is located southwest of the site, and Site 4 is to the northwest.

Site 21 was identified in November 1990 by WPNSTA Yorktown personnel and, therefore, had not been included in any previous investigations. Wastes noted and confirmed during a reconnaissance of Site 21 in October 1991 by Roy F. Weston, Inc. (WESTON) personnel included: various sized drums; batteries (Leclanche type); empty solvent containers; and scrap metal. Waste was noted throughout the site area with several areas of concentrated waste dumping (batteries and drums)

noted. Based on a geophysical investigation, the fill area was estimated to be approximately 200 feet by 200 feet, with apparently well-defined boundaries (Baker, 1993).

Site 21 was investigated as part of a subsurface soil study performed by IT in December 1992. This investigation indicated the presence of approximately 5 to 8 inches of topsoil under which batteries were present at thicknesses of 2 to 6 feet. The batteries were a carbon-zinc dry chemistry type, consistent with the type observed on the surface.

In 1994, IT performed a Removal Action at the site designed to remove identified wastes. Wastes were removed, in various quantities as discussed later in this report, from the majority of the site.

The site has been cleared in the area of the Removal Action. Small and large trees surround the removal action area and make up the remaining area of the site (based on a March 12, 1993 aerial photograph, the site was entirely covered with small and large trees prior to the removal action). A dirt road extending from West Road leads to the removal action area. The topography within the site is relatively steep; it falls sharply towards the on-site drainage way located along the western and southeastern portions of the site. Site elevations range from 5 to 45 feet above msl.

Site 22 - Burn Pad

Site 22 is located south of Site 4 and west of Site 21. A circular array of 11 steel burning pans was used for burning waste plastic explosives and spent solvents. The pans surround a 150-foot diameter circular area. Open burning operations at the Burn pad ceased in 1994. Site 22 was used for a treatability large scale study (TS) for the treatment of nitramine-contaminated soil and treatment area for TNT-contaminated soil. A 153-foot by 86-foot biocell was constructed at this site. Biocell operations ceased in 1998 and treated (clean) soil was pumped into an impoundment area which was established in the topographical low area located directly to the southeast of the existing biocell. This area served to dewater clean treated soil. In 1999, Site 22 received maintenance to prevent erosion to the wetlands located to the west of the biocell. An earthen dam built to hold clean soil and water in the impoundment area was also opened to prevent rainwater from overflowing into Felgates Creek.

Previous Investigations

Previous investigations completed through the IRP at WPNSTA Yorktown include the following:

- Initial Assessment Study (IAS) (C. C. Johnson & Associates, Inc., 1984)
- Confirmation Study (CS) Rounds One and Two Reports (Dames and Moore, 1986 and Dames and Moore, 1988)
- RI Interim Report (Versar, 1991)
- Site Inspection of Site 21 (WESTON, 1992)
- Round One RI Report (Baker/WESTON, 1993a)
- Focused Biological Sampling and Preliminary Risk Evaluation Report (Baker/WESTON, 1993b)
- Habitat Evaluation Report (Baker, 1994b)
- Removal Action at Sites 4 and 21 (IT, 1995)

The results of these reports have been utilized to conduct the Round Two Remedial Investigation.

ROUND TWO FIELD SAMPLING PROGRAM

The field investigation at Sites 4, 21, and 22 commenced in August 1996 with the collection of surface water, sediment, and biota samples within the eastern branch of Felgates Creek. The field investigation was continued in late October 1996 and was completed in mid November 1996 with the collection of surface, subsurface soil, and groundwater samples; and the installation of groundwater monitoring wells.

Soil Investigation

The soil investigation for Sites 4, 21, and 22 included the collection of both surface and subsurface soil samples in accordance with the Final Work Plan for Sites 4, 21, and 22 (Baker, 1996a). Surface soil samples were collected with stainless-steel spoons and aluminum pie pans, and subsurface soil samples were collected with a drill rig (split-spoon sampler) during the advancement of soil borings and the installation of monitoring wells.

The surface soil samples were analyzed for TCL volatile organics, TCL semivolatile organics, nitramine compounds (Sites 4 and 22 only), pesticides/PCBs, TAL inorganics, total organic carbon (TOC), nitrate/nitrite, and select samples were analyzed for cation exchange capacity (CEC).

The environmental subsurface soil samples were analyzed for TCL volatile organics, TCL semivolatile organics, nitramine compounds (Sites 4 and 22 only), pesticides/PCBs, TAL inorganics, TOC, and nitrate/nitrite. Select samples were analyzed for CEC, grain size, ph, and bulk density.

Groundwater Investigation

The Round Two RI groundwater sampling program developed for Sites 4, 21, and 22 was designed to determine if former site activities adversely impacted the quality of groundwater. Moreover, the program was developed to consider potential human health and ecological risks associated with the Contaminants of Potential Concern (COPCs).

In general, the field procedures and sampling methods employed for the groundwater investigation were implemented in accordance with USEPA Region III SOPs. These procedures also included sample handling and preservation, documentation, and chain-of-custody procedures.

The groundwater samples were analyzed for TCL volatile organics, TCL semivolatile organics dissolved nitramine compounds (Sites 4 and 22 only), TCL pesticides/PCBs, TAL inorganics (total and dissolved), and nitrate/nitrite.

Surface Water, Sediment, and Biota Investigation

Surface water and sediment samples were collected in August 1996 to ensure that the surface water conditions are consistent with when the background samples (WPNSTA Background Report, Baker, 1995) were collected.

Six surface water and sediment sampling stations were identified to characterize the east branch of Felgates Creek (including the unnamed tributary located between Sites 4 and 21). One surface water sample was collected from midstream at each sampling location. The surface water samples were analyzed for TCL organics, TAL inorganics, and TOC.

Sediment

Sediment sampling was conducted at all six of the surface water/sediment sampling stations and four additional sediment (only) locations at the southern portion of Site 22 (3 locations) and a small tributary to Felgates Creek west of Site 22 (1 location).

Surface (0- to 4-inches) and subsurface (4- to 8-inches) sediment samples were collected for chemical analysis with a sediment sleeve. The coring sleeve was pushed into the sediment to a depth of 12 inches or until refusal. The sediment samples were extruded with a decontaminated extruder into a laboratory-supplied and certified sampling bottle. The environmental soil samples were analyzed for TCL organics, TAL inorganics, TOC, ph, nitrite/nitrate and grain size.

Dioxin Investigation - Sites 4, 21, 22, and Background

In July 2000 thirteen surface soil samples (0- to 6-inches bgs) were collected throughout Naval Weapon Station Yorktown and analyzed for dioxins and dibenzofurans. Sites 4, 21, and 22 were identified as candidate sites for dioxin analysis because of the historic burning of explosives and waste materials that may have contained residual chlorinated solvents such as TCE.

Eight of the samples were collected at Sites 4, 21, and 22. Two of the samples were collected from Site 4 in the downgradient vicinity of the former ash pile. Two of the samples were collected from Site 21 in a depositional area downgradient of the Site 4 former ash pile, and four samples were

collected at Site 22 around the burn pad in areas downgradient of the predominant wind direction and in depositional areas. Figures 4-22, 4-23, and 4-24 present the sample locations. In addition, five surface soil samples were collected at background locations. Four of the sample areas were located at previous background surface soil locations (BS05, BS10, BS19, and BS31) and one location (BS41) was sampled at a new background location. Figure 4-25 presents the background sample locations.

The samples were collected with dedicated stainless steel spoons and bowls to a depth of 6-inches bgs. Care was taken to obtain undisturbed soils from each site that could have been affected by past disposal practices. Results from the Round Two RI were used to establish locations that were approved during formal partnering activities between LANTDIV, USEPA, and Virginia Department of Environmental Quality (VDEQ) personnel.

Round Two RI Analytical Results

The following subsections present analytical results for the environmental samples collected during the removal action at Sites 4 and 21, and the Round Two RI at Sites 4, 21, and 22. Analytical results are presented for the :

- Surface and subsurface soil investigation
- Groundwater investigation
- Surface water investigation
- Sediment investigation

Surface Soil Investigation Results-Site 4 Proper

The results of the Post-Removal Action Confirmatory sampling were used to select sampling locations for the Round Two RI. In general, the results of the Round Two surface soil investigation at Site 4 were consistent with the Round One results. Site 4-Proper consists of 51 surface soil samples collected throughout the site excluding samples 4SS34, 4SS35, 4SS36, and 4SS40 (which were designated Site 4 - Hot Spot).

Generally, low concentrations of at least one of four VOCs were detected within twenty-one of the forty-two samples (VOCs were not analyzed for the nine samples collected during the Round Two RI). Methylene chloride, acetone, 2-butanone, and toluene were the compounds detected.

Concentrations of the SVOCs [mainly Polynuclear Aromatic Hydrocarbons (PAHs)] were detected within twenty-nine of the fifty-one surface soil samples collected at Site 4-Propert. The majority of these detections were at low levels. Concentrations of benzo(a)anthracene, benzo(b)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, and dibenzo(a,h)pyrene exceeded the residential COC criteria.

Low concentrations of the pesticide compounds heptachlor, heptachlor epoxide, dieldrin, endrin, endosulfan II, 4,4-DDE, 4,4-DDD, 4,4-DDT, alpha-chlordane, and gamma-chlordane were detected within the sample set. None of the pesticide concentrations exceeded the residential COC criteria. In addition, concentrations of the PCBs aroclor-1254 and aroclor-1260 were detected in five of the samples of which only one (each) of the concentrations exceeded the COCs for residential soil.

Nitramine compounds were detected in six of the fifty-one surface soil samples. The compounds detected were 1,3-dinitrobenzene, 2,4,6-dinitrotoluene, 1,3,5-trinitrobenzene, HMX, RDX and total amino-DNTs. Two of the samples had concentrations exceeding the residential COC criteria for at least one of the detected compounds. The majority of the nitramine detections are located in the northeast portion of the site, downgradient of where an ash pile was removed during the removal action by IT Corporation (1995).

Nineteen of 20 inorganics were detected in surface soil samples. Silver was not detected in the sample set. All inorganic compounds were detected at levels exceeding Station-wide background concentrations in at least one of the samples. The following analytes aluminum, antimony, arsenic, beryllium, cadmium, copper, iron, manganese and zinc were detected above the residential COC criteria.

Surface Soil Investigation Results-Site 4 Hot Spot

The surface soil Hot Spot (AOC) is comprised of the sample locations: 4SS34, 4SS35, 4SS36 and 4SS40.

Generally, low concentrations of at least one of three VOCs were detected within two of the five samples (including one duplicate). Methylene chloride, 2-butanone, and trichloroethene were the compounds detected. None of the concentrations exceeded the residential COC criteria.

Concentrations of the SVOCs [mainly Polynuclear Aromatic Hydrocarbons (PAHs)] were detected within the five surface soil samples collected at Site 4-AOC. Concentrations of carbazole, benzo(a)anthracene, benzo(b)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, and dibenzo-(a,h)pyrene exceeded the residential COC criteria. Many of these compound concentrations exceeded 10 mg/kg.

Low concentrations of the pesticide compounds endrin aldehyde, endosulfan II, 4,4-DDE, 4,4-DDD, 4,4-DDT, and alpha-chlordane were detected within the sample set. None of the pesticide concentrations exceeded the residential COC criteria. In addition, concentrations of the PCB aroclor-1016 were detected in one of the samples below the concentrations of the RBCs for residential soil.

Nitramine compounds were not detected in any of the AOC surface soil samples.

Eleven of 20 inorganics were detected in AOC surface soil samples. Beryllium, cadmium, cobalt, mercury, nickel, selenium, silver, thallium, and cyanide were not detected in the sample set. Arsenic, lead and zinc were detected at levels exceeding Station-wide background concentrations in at least one of the samples.

Subsurface Soil Investigation Results

Subsurface soil samples were collected at the soil boring (4SB07 and 4SB08) and one of the new monitoring well locations (4SB06A).

Low concentrations of one VOC (toluene) and one SVOC [bis(2-ethylhexyl)phthalate] were detected in three subsurface soil samples.

Two pesticide compounds (4,4-DDT and methoxychlor) were detected within five samples at low concentrations. Nitramines were not detected in any of the subsurface soil samples.

Fourteen of 20 inorganics were detected within the subsurface soil samples. Antimony, cadmium, mercury, selenium, silver, and thallium were not detected in the sample set. The concentrations of all of the analytes were below Station-wide background levels with the exception of chromium which slightly exceeded the background levels. Concentrations of aluminum, arsenic, beryllium and iron exceeded the residential COC criteria.

Groundwater Investigation Results

The following subsections discuss the results of samples collected from the Yorktown-Eastover aquifer at Site 4.

VOCs, pesticides, and nitramines were detected in eight of the ten groundwater samples collected at Site 4.

Three of the monitoring wells (4GW03, 4GW04, and 4GW05) had concentrations of 1,2-dichloroethene and trichloroethene. The highest concentration of trichloroethene (9 µg/L) detected in 4GW04 and 4GW05 exceeded the Federal MCLs and the Commonwealth of Virginia PMCLs. These compounds were also detected (at the same well locations) during the Round One sampling event but at slightly lower concentrations. These monitoring wells are located between Sites 4 and 22.

Low concentrations of seven pesticides were detected in one monitoring well (4GW06A). None of the concentrations exceeded the Federal MCLs or Commonwealth of Virginia PMCLs. These pesticide concentrations were not detected within any of the samples collected from the other wells (shallow or deep) and are detected below the contract required detection limits.

Four explosive compounds (2,4-DNT/2,6-DNT, 2,4,6-TNT, amino-DNTs, and RDX) were detected at relatively low levels within five groundwater samples from the monitoring wells: 4GW03, 4GW05, 4GW05A, and 4GW06.

Relatively low concentrations of total inorganics were detected in the groundwater samples. Twelve of 19 inorganics were detected within the sample set. Only concentrations of arsenic, barium, chromium, copper and manganese exceeded station-wide maximum background levels.

Concentrations of aluminum and manganese exceeded the Federal MCLs and concentrations of chromium, iron and manganese exceeded the Commonwealth of Virginia PMCLs.

Nine of 20 dissolved inorganics were detected in the sample set. Antimony, beryllium, cadmium, copper, lead, mercury, selenium, silver, thallium, and zinc were not detected. Concentrations of dissolved inorganics exceeded Station-wide background levels for the following analytes: arsenic, barium, chromium, cobalt, manganese, nickel, and vanadium. Concentrations of iron, manganese and nickel exceeded the Federal MCLs and concentrations of iron and manganese exceeded the Commonwealth of Virginia PMCLs.

Although contaminant concentrations were compared to the Federal MCLs and the Commonwealth of Virginia PMCLs, the groundwater samples were collected from an aquifer (Yorktown-Eastover) that can be considered a Type III aquifer within the WPNSTA area. Previous sampling of the groundwater within the Cornwallis Cave and Yorktown-Eastover aquifers have generated results that suggest generally poor quality and low yields that are consistent with the characteristics of a Type III aquifer.

Surface Water and Sediment Investigation

The following subsections present a discussion on the analytical results for surface water and sediment samples collected in within the east branch of Felgates Creek, the unnamed tributary to east branch of Felgates Creek between Sites 4 and 21, and within the marsh area adjacent to the main body of Felgates Creek west of Site 22. The surface water/sediment sample labels reference Site 4 (i.e., SW/SD 07) but are representative of the surface water/sediment that drains all 3 sites.

Surface Water Investigation Results

Seven surface water samples were collected from the east branch of Felgates Creek, the unnamed tributary, and the marsh area adjacent to the main body of Felgates Creek. There was no surface water at location 4SW/SD13 (marsh area west of Site 22) therefore only a sediment sample could be collected.

No VOCs or pesticides/PCBs were detected in the samples. Only one SVOC [bis(2-ethylhexyl) phthalate] was detected in the sample set.

Eight nitramine compounds (amino-DNT, 1,3-dinitrobenzene, 2,4-DNT/2,6-DNT, HMX, RDX, nitrobenzene, 1,3,5-trinitrobenzene, and 2,4,6-trinitrotoluene) were detected within the surface water samples. The majority of detections (4SW07 and 4SW08) were located within the upstream portion of the unnamed tributary that discharged into the east branch of Felgates Creek between Sites 4 and 21. These two samples (4SW07 and 4SW08) were located downstream of surface soil locations that had similar nitramine compounds detected.

Twelve of 20 inorganics were detected within the sample set. Beryllium, mercury, nickel, selenium, silver, thallium, zinc, and cyanide were not detected within the sample set. Antimony, arsenic, and manganese exceeded the BTAG surface water screening levels. Only antimony and chromium exceeded the maximum Station-wide background concentrations.

Sediment Investigation Results

Seven surface water samples were collected from the east branch of Felgates Creek, the unnamed tributary, and the marsh area adjacent to the main body of Felgates Creek east of Site 22.

VOCs, SVOCs, pesticides, and nitramines were detected in the sediment samples collected within the water bodies previously described. Three VOCs (benzene, carbon disulfide, 2-butanone, and tetrachloroethene) were detected at relatively low concentrations. The maximum detected concentrations were within samples 4SD09-01, 4SD10-01D, and 4SD11-02.

Seven SVOCs were detected in one sample (4SD07-02). The SVOCs were mainly PAHs and the at relatively low levels. None of the concentrations exceeded the sediment screening levels.

Two pesticide compounds were detected in two samples (4SD09-02 and 4SD13-01). The concentrations exceeded the sediment screening levels.

One nitramine compound (2,4,6-TNT) was detected in eight samples (four locations). The concentrations were all below the sediment screening levels.

Nineteen of 20 inorganics were detected in the sediment samples. Cyanide was not detected within the sample set. Antimony, cadmium, chromium, cobalt, iron, mercury, nickel, vanadium, and zinc exceeded the maximum Station-wide background levels. Concentrations of aluminum, arsenic, antimony, beryllium, cadmium, chromium, iron, and manganese and vanadium exceeded the residential COC criteria.

Site 21 Investigative Results

The following sections present analytical results for the environmental samples collected during the Round Two RI at Site 21 by media.

Surface Soil Investigation Results

Five surface soil samples (21SS19 through 21SS22, including one duplicate) were collected during the Round Two RI downgradient along the west and south west portions of the site. These samples were analyzed for SVOCs, pesticide/PCBs, TAL inorganics, and engineering parameters. In addition, twelve surface soil samples (21SS01 through 21SS05, 21SS09, 21SS11, 21SS12, and 21SS15 through 21SS18) were collected after the removal action (performed by IT Corp.). These samples were analyzed for VOCs, SVOCs, pesticide/PCBs, nitramine compounds, and TAL inorganics.

Low concentrations of four VOCs (methylene chloride, acetone, toluene and styrene) were detected within the sample set. VOCs were not analyzed for the Round Two surface soil samples. Thirteen SVOCs (mainly PAHs) were detected at relatively low concentrations within the sample set. Concentrations of benzo(b)fluoranthene and benzo(a)pyrene exceeded the residential COC criteria in one sample (21SS15). In addition, relatively low concentrations of thirteen pesticides were detected in the sample set. Concentrations of dieldrin in one sample slightly exceeded residential COC criteria for residential soil (21SS01). There were no nitramine compounds detected within the sample set (Removal Action).

Nineteen of 20 inorganics were detected in the surface soil samples. Antimony was not detected within the sample set. Inorganic concentrations exceeded Station-wide background levels in ten of

the samples for at least one or more of the following analytes: aluminum, cadmium, chromium, copper, iron, manganese, mercury, selenium, thallium, vanadium, zinc, and cyanide. In addition, concentrations of aluminum, arsenic, beryllium, cadmium, iron, manganese, mercury, and zinc exceeded the residential COC criteria.

Subsurface Soil Investigation Results

Six subsurface soil samples were collected at six locations at 0.5- to 1.5-ft bgs as part of the post removal action and analyzed for TCL organics, nitramine compounds, and TAL inorganics. In addition, one soil sample (21SB04-001) and a duplicate (21SB04-101) were collected from the soil boring due to the shallow depth of the groundwater. These two samples were analyzed for TCL organics and TAL inorganics.

Low concentrations of four VOCs (methylene chloride, acetone, toluene and xylenes) were detected in the sample set. None of the concentrations exceeded the residential COC criteria.

Low concentrations of nine SVOCs, five pesticides and one PCB were detected in the sample set. None of the concentrations exceeded the residential COC criteria.

Nitramines were not detected in the subsurface soil samples.

Twelve of 20 inorganics were detected in the subsurface soil samples. Antimony, cadmium, cobalt, nickel, silver, thallium, and cyanide were not detected within the sample set. Concentrations of copper, lead, mercury, and zinc were detected above Station-wide background levels and concentrations of arsenic, beryllium, iron and manganese exceeded the residential COC criteria.

Groundwater Investigation Results

Five groundwater samples were collected from three existing monitoring wells and one new monitoring well (21GW01A) at the site during the Round Two RI and analyzed for TCL organics, nitramine compounds, and TAL inorganics (total and dissolved). The existing monitoring well 21GW01 was not sampled because it is upgradient and not hydraulically connected to the site (well constructed within the Columbia aquifer while the other wells are situated within the lower aquifer).

Low concentrations of the VOCs trichloroethene (21GW03) and 1,2-dichloroethene (21GW01A) were detected in the samples. These concentrations did not exceed the Federal MCLs or the Commonwealth Virginia PMCLs.

One pesticide compound (heptachlor) was detected below the Federal MCL in one monitoring well (21GW04).

Relatively low concentrations of fourteen total inorganics were detected in the groundwater samples. Antimony, beryllium, cadmium, mercury, silver, and thallium were not detected in the samples. Concentrations of cadmium, iron, manganese and zinc exceeded the Federal MCLs and the Commonwealth of Virginia PMCLs. In addition, concentrations of cadmium, cobalt, manganese, nickel, selenium, and zinc exceeded the Station-wide background levels.

Relatively low concentrations of eleven dissolved inorganics were detected in the groundwater samples. Aluminum, antimony, beryllium, chromium, copper, lead, silver, and thallium were not detected within the sample set. Concentrations of cadmium, iron and manganese exceeded the Federal and the Commonwealth of Virginia MCLs. In addition, concentrations of barium, cadmium, cobalt, iron, manganese, mercury, nickel, and zinc exceeded the Station-wide background levels.

Although contaminant concentrations were compared to the Federal MCLs and the Commonwealth of Virginia PMCLs, the groundwater samples were collected from an aquifer (Yorktown-Eastover) that can be considered a Type III aquifer within the WPNSTA area. Previous sampling of the groundwater within the Cornwallis Cave and Yorktown-Eastover aquifers have generated results that suggest generally poor quality and low yields that are consistent with the characteristics of a Type III aquifer.

Site 22 Analytical Results

The following sections present analytical results for the environmental samples collected during the Round Two RI at Site 22 by media.

Surface Soil Investigation Results

Twenty-six surface soil samples (22SS01 through 22SS23, including three duplicates) were collected prior to the construction of the biocell at Site 22. The samples were analyzed for TCL organics (excluding VOCs), nitramine compounds, TAL inorganics.

Low concentrations of the SVOCs [(mainly Polynuclear Aromatic Hydrocarbons (PAHs))] were detected within surface soil samples collected at Site 22. Concentrations of n-nitroso-di-n-propylamine and benzo(a)pyrene exceeded residential COC criteria within one sample for each compound.

Low concentrations of seven pesticide compounds (beta-BHC, heptachlor epoxide, dieldrin, 4,4-DDE, 4,4-DDT, alpha-chlordane, and gamma-chlordane) were detected within the sample set. None of the pesticide concentrations exceeded the residential RBCs.

Five nitramine compounds were detected in surface soil samples. The compounds detected were 2,4,6-dinitrotoluene, 1,3,5-trinitrobenzene, HMX, RDX and total amino-DNTs. None of the compound concentrations exceeded the residential COC criteria.

Nineteen of 20 inorganics were detected in surface soil samples. Thallium was not detected in the sample set. Cadmium, chromium, copper, iron, lead, mercury, selenium, silver, vanadium, zinc, and cyanide were detected at levels exceeding Station-wide background concentrations in at least one of the samples. In addition, aluminum, arsenic, beryllium, cadmium, chromium, copper, iron, lead, and manganese were detected above the residential COC criteria.

Subsurface Soil Investigation Results

Subsurface soil samples were collected at the new monitoring well locations.

Low concentrations of three VOCs (acetone, carbon disulfide, and toluene) and one SVOC [bis(2-ethylhexyl)phthalate] were detected in the sample set. None of these concentrations exceeded the residential COC criteria.

Low concentrations of seven pesticide compounds were detected within sample set. All of the pesticide concentrations were below the residential COC criteria. Three nitramine compounds (2,4,6-trinitrotoluene, HMX, and RDX) were detected at concentrations below the residential COC criteria.

Seventeen of 20 inorganics were detected within the subsurface soil samples. Cadmium, silver, and cyanide were not detected in the sample set. The concentrations of chromium, iron, lead, mercury, selenium, thallium, and vanadium exceeded Station-wide background levels. Concentrations of aluminum, arsenic, beryllium, chromium, iron, thallium, and vanadium exceeded the residential COC criteria.

Groundwater Investigation Results

The following subsections discuss the results of samples collected from the Yorktown-Eastover aquifer at Site 22.

VOCs, SVOCs, pesticides, and nitramine compounds were detected in the sample set.

Four of the monitoring wells (22GW01, 22GW01A, 22GW04, and 22GW05) had detectable VOC concentrations. Concentrations of 1,1-dichloroethene, 1,2-dichloroethene, 1,2-dichloroethane, 1,1,1-trichloroethane and trichloroethene exceeded the Federal MCLs and the Commonwealth of Virginia PMCLs. The highest concentration of trichloroethene (1,200 µg/L) was detected in 22GW04.

Low concentrations of three SVOCs and one pesticide compound were detected. The concentrations did not exceed the Federal MCLs or Commonwealth of Virginia PMCLs.

Three explosive compounds (HMX, RDX, and tetryl) were detected within five groundwater samples from the monitoring wells (22GW01, 22GW01A, 22GW02, 22GW03 and 22GW04).

Relatively low concentrations of total inorganics were detected in the groundwater samples. Ten of 19 inorganics were detected within the sample set. Only concentrations of barium, beryllium, and

manganese exceeded Station-wide maximum background levels. None of the detected inorganic concentrations exceeded the Federal MCLs or the Commonwealth of Virginia PMCLs.

Eleven of 19 dissolved inorganics were detected in the sample set. Antimony, cadmium, chromium, copper, lead, silver, thallium, and vanadium were not detected within the sample set. Concentrations of dissolved inorganics exceeded Station-wide background levels for the following analytes: aluminum, beryllium, cobalt, iron, manganese, mercury, and nickel. Concentrations of iron and manganese exceeded the Federal MCL and the Commonwealth of Virginia PMCLs.

Although contaminant concentrations were compared to the Federal MCLs and the Commonwealth of Virginia PMCLs, the groundwater samples were collected from an aquifer (Yorktown-Eastover) that can be considered a Type III aquifer within the WPNSTA area. Previous sampling of the groundwater within the Cornwallis Cave and Yorktown-Eastover aquifers have generated results that suggest poor quality and low yields that are consistent with the characteristics of a Type III aquifer.

Sediment Investigation

The following subsections present a discussion on the analytical results for sediment samples collected in within marsh area at the southern portion of Site 22.

VOCs, SVOCs, pesticides and nitramine compounds were detected in of the sediment samples. Two VOCs (carbon disulfide and 2-butanone) were detected at relatively low concentrations.

Three SVOCs (di-n-butylphthalate, flouranthene, pyrene, and benzo(b)flouranthene) were detected within the sample set at low levels (below the sediment screening levels).

Three pesticide compounds (4,4-DDD, alpha-chlordane, and gamma-chlordane) were detected within the sample set. The concentrations were below the sediment screening levels (effect range-low).

One nitramine compound (2,4,6-TNT) was detected in one sample (22SD01-01) at low levels.

Seventeen of 20 inorganics were detected in the sediment samples. Mercury, vanadium and cyanide were not detected within the sample set. Aluminum, antimony, arsenic, iron, manganese, and

vanadium exceeded the residential COC criteria. All of the analytes had concentrations exceeding the maximum Station-wide background levels except for arsenic, barium, and manganese.

Dioxin Results

In July 2000 thirteen surface soil samples (0- to 6-inches bgs) were collected throughout Naval Weapon Station Yorktown and analyzed for dioxins and dibenzofurans. Eight of the samples were collected at

Sites 4, 21, and 22 and five surface soil samples were collected at background locations.

The results of the dioxin sampling are presented on Table 4-41 and Figures 4-22, 4-23, 4-24, and 4-25. The results for Sites 4, 21, and 22 were similar to WPNSTA background results. The site results and background results were below the Agency for Toxic Substances and Disease Registry (ASTDR) environmental media evaluation guide (EMEG) value of 50 part-per-trillion (ppt). Results below the ASTDR EMEG value suggest that levels of dioxin detected at the sites will not cause adverse human health or environmental effects subsequent to exposure.

Extent of Contamination

This section describes the extent to which contamination has migrated at Sites 4, 21 and 22. Note that the discussion focuses on organic contamination. Inorganic constituents were detected in all the media sampled as part of the Round Two investigation. Based on a review/evaluation of the data, no trends or hot spots of inorganic contamination were identified.

Site 4

The extent of the surface water and sediment are discussed in this section for Site 4. This discussion, however, represents Sites 4, 21, & 22.

Surface Soil

Low concentrations of VOCs were detected sporadically and generally at low frequencies. Most of the detections (methylene chloride, acetone, 2-butanone) could be associated with common

laboratory contaminants. The low levels of trichloroethene and toluene may be due to past disposal practices.

Following evaluation of data collected during the Round Two RI, concentrations of SVOCs which were identified as soil contaminants across the site are consistent with the analytical results from the Round One sampling event. The concentrations of SVOCs (mainly PAHs) were generally spread throughout the landfill and not exhibit a pattern except at the AOC where elevated levels of PAHs were detected. The SVOCs detected were possibly related to past disposal practices (disposal of asphalt, roofing tar, utility poles, and miscellaneous construction material).

Low concentrations of detected pesticides were consistent with historical use of Station-wide spraying. Low levels of PCB compounds were detected in surface soils within the same area as they were detected in this Round One RI (along the gravel road traversing through the site). Like the pesticide compounds, the PCB detections may be attributed the application of oil to suppress the dust on the roadways.

Explosives were within the detected surface soil at the northeast portion of the site. The detection of these compounds was isolated and may be indicative of past disposal practices. These compounds were detected downgradient from where similar compounds were detected in the Round One RI (the area of this detection was removed by IT Corp.)

Most of the inorganics (19 of 20) were detected within the surface soil samples. The majority of them were sporadic and at low frequencies. Concentrations of arsenic, beryllium, iron, and zinc were detected at a greater rate. These inorganics may be attributed to past disposal practices.

Overland transport of contaminated soils by runoff flowing toward Site 22 and to the unnamed tributary to the east branch of Felgates Creek is a potential pathway for surface soil contaminant migration. Analytical results from surface water/sediment samples collected in the unnamed tributary indicate that the surface soil contaminants (explosives) detected at Site 4 may have migrated to or had an impact on this surface water body.

The surface soil at Site 4 (with the exception of the AOC) has not been significantly impacted by site operations. There is no apparent source or discernible pattern of contamination within this media.

Subsurface Soil

Results of the subsurface soil investigation at Site 4 indicate that low levels of one VOC (toluene), one SVOC [bis(2-ethylhexyl)phthalate], and two pesticide compounds (4,4-DDT and methoxychlor) were detected at low frequencies. Due to the low concentrations and the sporadic appearances at the site, these compounds do not appear to be associated with the past disposal practices at the site.

Inorganics detected within the subsurface soil were similar to inorganics detected within the surface soils. The relatively low concentrations were within the Station-wide background levels.

The subsurface soil at Site 4 has not been significantly impacted by site operations. There is no apparent source or discernible pattern of contamination within this media. The leaching of subsurface soil contaminants to groundwater is a potential contaminant migration pathway. Organic contaminants detected in groundwater at Site 4 have likely migrated through (or from) the subsurface soils. The analytical results from the subsurface soil samples collected during this investigation; however, indicates that this media is not currently acting as a source of groundwater degradation at Site 4.

Groundwater

This section addresses the extent of groundwater contamination at Site 4. Possible sources of groundwater contamination and potential migration of contamination are also evaluated.

During the Round Two RI, shallow and a deep monitoring wells were installed within the shallow and deeper Yorktown-Eastover aquifer at Site 4 to determine the horizontal and vertical extent of groundwater contamination.

Results from the Round Two RI indicated that the horizontal extent of VOC and nitramine contamination (chlorinated solvents and explosives) detected in the Round One RI at Site 4 is limited to the southern portion of the landfill adjacent to Site 22. The highest concentrations of TCE

were detected at 4GW05 and 4GW04 at 9J µg/L. TCE was not detected at depth within monitoring wells 4GW06A (65-ft depth) or 4GW02A (80.5-ft depth). Nitramine compounds (RDX, 2,4/2,6-dinitrotoluene, 2,4,6-trinitrotoluene, and amino-DNTs) were also detected within the shallow portion of the aquifer at relatively low concentrations and at low frequencies. These compounds were not detected at greater depths within the aquifer. The VOC and nitramine compounds detected at the site may be attributed to past site operations. Although pesticide compounds were detected well below the Federal MCLs and the Commonwealth of Virginia PMCLs, these results may not be accurate. Pesticides were detected in the deep monitoring well 4GW06A and not in the shallow well, immediately adjacent, which would be expected if the results reflected actual conditions.

Concentrations of inorganics in shallow groundwater were generally within the range of the Station-wide levels for both total and dissolved fractions (with the exception of manganese which exceeded the Federal MCLs for both the total and dissolved fractions).

The vertical extent of groundwater contamination appears to be limited to the shallow portion of the Yorktown-Eastover aquifer. Groundwater flow at Site 4 is generally toward the south (Site 22). The horizontal extent of groundwater contamination is limited to a southern area adjacent to Site 22. The characteristics of the groundwater within the Yorktown-Eastover aquifer from past sampling efforts at WPNSTA suggest generally poor quality and low yields that are consistent with the characteristics of a Type III aquifer (i.e., limited beneficial use).

Surface Water

The Round Two RI surface water analytical results were consistent with the Round One RI results for Sites 4, 21, and 22. VOCs, SVOCs, and pesticides/PBS were not detected in the surface water. Nitramine compounds were detected within the unnamed tributary to the east branch of Felgates Creek. Generally, more compounds were detected upstream at greater concentrations. In addition, nitramine compounds were detected in surface soil samples at the eastern portion of Site 4, which may indicate migration of surface soil contaminants to the surface water.

The inorganic concentrations detected within the surface water were generally within the range of Station-wide background levels.

Sediment

Relatively low concentrations of VOCs, SVOCs, nitramine and pesticide compounds were detected within the sediment samples. These concentrations may be associated with residual contaminant migration from Site 4.

The concentrations of detected inorganic compounds were generally within the range of Station-wide background levels.

The sediment within the study area has not been significantly impacted by operations at Sites 4, 21, and 22. There is no apparent source or discernable pattern but at significantly lower concentrations.

Site 21

Surface Soil

Low concentrations of VOCs were detected sporadically and generally at low frequencies. Most of the detections (methylene chloride, acetone,) could be associated with common laboratory contaminants. The low levels of toluene may be contributed to past disposal practices.

Low concentrations of SVOCs (mainly PAHs) were generally spread throughout the site and did not exhibit a pattern.

Low concentrations of pesticides that were detected are consistent with historical use of Station-wide spraying.

Most of the inorganics (19 of 20) were detected within the surface soil samples at relatively low concentrations. Concentrations of aluminum, arsenic, beryllium, cadmium, iron, manganese, mercury, thallium and zinc were detected at either higher concentrations or greater frequency. These inorganics may be attributed to past disposal practices (of batteries, scrap metal, and construction debris).

Overland transport of contaminated soils by runoff flowing toward the unnamed tributary to the east branch of Felgates Creek is a potential pathway for surface soil contaminant migration. Analytical results from surface water/sediment samples collected in the unnamed tributary indicates that the surface soil contaminants detected at Site 21 have not had significant impact on this surface water body.

The surface soil at Site 21 has not been significantly impacted by site operations. There is no apparent source or discernible pattern of contamination within this media.

Subsurface Soil

Results of the subsurface soil investigation at Site 21 indicate low levels of VOCs (acetone, methylene chloride, and toluene). These compounds do not appear to be the result of past disposal activities. Methylene chloride and acetone are common laboratory contaminants, and toluene.

Low concentrations of SVOCs were detected sporadically throughout the site and did not exhibit a pattern. These SVOC compounds do not appear to be associated with the site .

Five pesticide compounds (4,4-DDT 4,4-DDE 4,4-DDD, alpha-chlordane and gamma-chlordane) were detected at low concentrations and at low frequencies. Due to the low concentrations and the sporadic appearances at the site, these compounds do not appear to be associated with the past disposal practices at the site.

Inorganics detected within the subsurface were similar to inorganics detected within the surface soils. The relatively low concentrations were within the Station-wide background levels.

The subsurface soil at Site 21 has not been significantly impacted by site operations. There is no apparent source or discernable pattern of contamination within this media. The leaching of subsurface soil contaminants to groundwater is a potential contaminant migration pathway. Organic contaminants detected in groundwater at Site 21 have likely migrated through (or from) the subsurface soils. The analytical results from the subsurface soil samples collected during this investigation, however, indicate that this media is not currently acting as a source of groundwater degradation at Site 21.

Groundwater

This section addresses the extent of groundwater (Yorktown-Eastover) contamination at Site 21. Possible sources of groundwater contamination and potential migration of contamination are also evaluated.

Results of the Round Two RI indicated that low levels of VOCs were detected in two monitoring wells at Site 21. The concentrations detected were below the Federal MCLs and the Commonwealth of Virginia PMCLs. Although past sampling events did not detect these VOCs, empty cans of solvents were discovered during a reconnaissance of the site (Baker, 1996).

Concentrations of inorganics in shallow groundwater were generally within the range of the Station-wide levels for both total and dissolved fractions (with the exception of manganese and zinc) which may be related to the batteries that were disposed at the site.

The contaminants detected in groundwater at Site 21 are sporadic and at low concentrations. Groundwater flow at Site 21 is generally toward the unnamed tributary that flows to Felgates Creek. It does not appear that past site operations have had an adverse impact the groundwater at the site. In addition, the characteristics of the groundwater within the Yorktown-Eastover aquifer from past sampling efforts at WPNSTA suggest generally poor quality and low yields that are consistent with the characteristics of a Type III aquifer (i.e., limited beneficial use).

Site 22

Surface Soil

Low concentrations of SVOCs (mainly PAHs) are generally spread throughout the site. The SVOCs detected are possibly related to past site activities of burning solvents and explosives.

Low concentrations of pesticides which were detected are consistent with historical use of Station-wide spraying.

Low concentrations of explosives were detected within surface soil samples at the site. The detection of these compounds was isolated and may be indicative of past site activities.

Most of the inorganics (19 of 20) were detected within the surface soil samples. The majority of them were sporadic and at low frequencies. Concentrations of arsenic, beryllium, cadmium, copper, iron, lead and manganese were detected at higher concentrations. These inorganics may be attributed to past site activities.

Overland transport of contaminated soils by runoff flowing toward the east branch of Felgates Creek 22 is a potential pathway for surface soil contaminant migration. Analytical results from surface water/sediment samples collected in Felgates Creek do not indicate adverse effects from contaminant migration from surface soil.

The surface soil at Site 22 has not been significantly impacted by site operations.

Subsurface Soil

Results of the subsurface soil investigation at Site 22 indicate that low levels of VOCs , one SVOC (acetone, carbon disulfide, and toluene) (Bio [2-ethyl hexyl] phthalate), nitramine and pesticide compounds were detected at low the concentrations and at low frequencies.

Inorganics detected within the subsurface were similar to inorganics detected within the surface soils. The relatively low concentrations were within the Station-wide background levels.

The subsurface soil at Site 22 has not been significantly impacted by site operations. There is no apparent source or discernable pattern of contamination within this media. The leaching of subsurface soil contaminants to groundwater is a potential contaminant migration pathway. Organic contaminants detected in groundwater at Site 22 have likely migrated through (or from) the subsurface soils. The analytical results from the subsurface soil samples collected during this investigation, however, indicates that this media is not currently acting as a source of groundwater degradation at Site 22.

Groundwater

This section addresses the extent of groundwater contamination at Site 22. Possible sources of groundwater contamination and potential migration of contamination are also evaluated.

During the Round Two RI, shallow and deep monitoring wells were installed within the shallow and deeper (Yorktown-Eastover) aquifer, at Site 22 to determine the horizontal and vertical extent of groundwater contamination. The characteristics of the groundwater within the Yorktown-Eastover aquifer from past and current sampling efforts at WPNSTA suggest generally poor quality and low yields that are consistent with the characteristics of a Type III aquifer.

Results of the Round Two RI indicated that the horizontal extent of VOC and nitramine contamination (chlorinated solvents and explosives) detected at Site 22 was most prevalent in the southern half of the site. The highest concentrations of TCE were detected at 22GW04 at 1,200 µg/L. This well also had the highest concentrations of RDX at 110 µg/L. This well is located adjacent to the burn area. The VOC and nitramine compounds detected at the site appear to be attributed to past site operations. Detections of similar compounds were observed within the samples collected from monitoring wells 22GW01 and 22GW01A at lower (one order of magnitude) concentrations.

Concentrations of inorganics in shallow groundwater were generally within the range of the Station-wide levels for both total and dissolved fractions (with the exception of iron and manganese which exceeded the Federal MCLs for both the total and dissolved fractions).

The vertical extent of groundwater contamination appears to be limited to the shallow portion of the Yorktown-Eastover aquifer. The concentrations detected in the deeper (55-ft bgs) portion of the aquifer are generally one order of magnitude lower. In addition, the characteristics of the groundwater within the Yorktown-Eastover aquifer from past and current sampling efforts at WPNSTA suggest generally poor quality and low yields that are consistent with the characteristics of a Type III aquifer (i.e., limited beneficial use).

Groundwater flow at Site 22 is toward the east branch of Felgates Creek. Surface water and sediment samples collected down gradient of Site 22 do not exhibit VOC contamination. The groundwater at Site 22 does not appear to adversely impact the surface water and sediment within Felgates Creek.

Sediment

Relatively low concentrations of VOCs, SVOCs, nitramine and pesticide compounds were detected within the sediment samples collected within the marsh area at the southern portion of Site 22. These may be associated with residual contaminant migration from Site 22.

The concentrations of inorganics were detected within the samples were generally within the range of Station-wide background levels.

The sediment within the study area has not been significantly impacted by operations at Site 22.

RESULTS AND CONCLUSIONS

The purpose of this section is to summarize the potential for unacceptable human health risks and adverse ecological effects associated with contaminated media at Sites 4, 21 and 22. Results presented herein will focus on those media and chemicals having the potential to cause unacceptable human health risks under current and future land use scenarios and the ecology, both terrestrial and aquatic. Contaminants responsible for unacceptable risks will be compared to Station-wide and anthropogenic background levels for discussion purposes.

Human Health Risks

The human health risk assessment for Sites 4, 21 and 22 evaluated the potential exposure of current and future human receptors to affected soil, groundwater surface water and sediment. The following receptors were evaluated under the following land use scenarios:

Current Land use Scenario

- Commercial/Utility Workers
- Older Child Trespassers (ages 7 to 15 years)
- Adult Trespassers

Future Land use Scenario

- Child Residents (ages 1 to 6 years)
- Older Child Residents (ages 7 to 15 years)
- Adult Residents
- Construction Workers

Both reasonable maximum exposure (RME) and central tendency (CT) estimates of exposure were calculated for each of the aforementioned receptors. Exposure pathways include dermal contact, accidental ingestion and inhalation of particulates from surface soil. Because of general groundwater quality and relatively poor yields from both the Cornwallis Cave and Yorktown Eastover aquifers observed throughout the Station, groundwater was evaluated using a beneficial use scenario such as water lawns and washing cars.

Site 4

Site 4 was evaluated as soil Hot Spot and as Site 4 - Proper. The soil Hot Spot was separated out of the Site 4 database because of the presence of relatively high concentrations of PAHs and inorganic constituents. Arsenic in surface soil contributed approximately 55% of the ILCR value of 4.7×10^{-4} , a value that exceeds the upper end of USEPA's generally acceptable risk range of 1×10^{-6} to 1×10^{-4} . PAHs in surface soil contribute an additional 3.9×10^{-4} (approximately 45%) to the overall ILCR value.

Inorganic constituents detected in surface soil are responsible for an HI value of 3.2. However arsenic is the only inorganic constituent with a hazard quotient (HQ) value equal to or exceeding 1.0 (2.9). Arsenic in the Site 4 - Hot Spot exceeds 63.9 mg/Kg (the upper end of Station-wide background values).

PAHs and arsenic were also detected in surface soil collected from Site 4 - Proper. ILCR values for potential current property use scenarios fall within the generally acceptable risk range. HI values are below 1.0 when evaluated by target organ, with the exception of future residents. An HI value of 4.28 was derived assuming exposure to surface soil under this future property use scenario. Table 8-3 presents contaminants and percent contributions to ILCR and HI values for future residents. The inorganic constituent manganese accounted for 53% of the HI value (HQ=2.27). Manganese also exceeded Station-wide surface soil background concentrations. Iron, aluminum and arsenic were contributors to the total HI value but do not produce individual HQ values in excess of 1.0 and concentrations of these constituents are generally within Station-wide background values.

Site 21

An evaluation of potential current trespassers and future residents exposed to site media produces HI values of 2.0 and 4.1, respectively. These values fall below 1.0 when constituent contributions to target organs are considered. ILCR values fall within the generally acceptable risk range for all receptors, media and pathways evaluated at Site 21.

Site 22

As with Site 21, an evaluation of potential current trespassers and future residents exposed to site media produces HI values of 2.0 and 4.7, respectively. These values fall below 1.0 when constituent contributions with respect to target organs are considered. ILCR values fall within the generally acceptable risk range for all receptors, media and pathways evaluated at Site 22.

Ecological Risk Assessment Summary

The following subsections provided a summary of the potential ecological risks identified in this RA for each site. Summaries regarding screening levels are highly conservative and reflect potential risks to terrestrial or aquatic flora and fauna. These data were used to select ECOCs. Discussions regarding upper trophic level receptors discuss potential risks for conservative and less conservative scenarios.

Site 4 - Soil Hot Spot - Terrestrial Receptors

Based on a screening of soil concentrations against flora/fauna toxicity values, the terrestrial environment at Site 4 - Soil Hot Spot potentially may be adversely impacted by soil concentrations of 21 SVOCs, 4,4'-DDT, endosulfan II, aluminum, antimony, arsenic, chromium, iron, vanadium, and zinc.

Conservative upper trophic level receptor models suggest that surface soil concentrations of PAHs and inorganics produce HQ values above 1.0 for the red fox, american robin, meadow vole, short tailed shrew, deer mouse, american woodcock, marsh wren, and red-tailed hawk. Inorganics produced HQ values above 1.0 for the bob white quail.

Less conservative upper trophic level receptor models for Site 4 - Soil Hot Spot indicate potential risks to the red fox and deer mouse from surface soil concentrations of PAHs, aluminum, antimony, and arsenic. To a lesser extent inorganics (mainly aluminum and arsenic) produce HQ values above 1.0 for the bobwhite quail, american robin, meadow vole, short-tailed shrew, american woodcock, and marsh wren.

Site 4 - Proper - Terrestrial Receptors

Based on a screening of soil concentrations against flora/fauna toxicity values, the terrestrial environment in Site 4 - Proper potentially may be adversely impacted by soil concentrations of 14 SVOCs, 4,4'-DDD, 4,4'-DDT, endosulfan II, aroclor-1254, aroclor-1260, 2,4,6-trinitotoluene, 1,3-dinitrobenzene, 1,3,5-trinitrobenzene, amino-dinitrotoluenes, HMX, RDX, aluminum, cadmium, chromium, copper, cyanide, iron, lead, manganese, mercury, vanadium, and zinc.

Conservative upper trophic level receptor models suggest that surface soil concentrations of PAHs and inorganics produce HQ values greater than 1.0 for the red fox. Inorganics and PCB compounds produce elevated (above 1.0) HQ values for the american robin, short tailed shrew, deer mouse, american woodcock, and marsh wren. Inorganics produce HQ values above 1.0 for the bobwhite quail, meadow vole, and red-tailed hawk.

Less conservative upper trophic level receptor models for Site 4 - Proper indicate potential risks to red fox, american robin, meadow vole, short tailed shrew, deer mouse, american woodcock, and marsh wren from surface soil concentrations of aluminum, arsenic, cadmium, chromium, lead, mercury, vanadium and zinc.

Site 4 - Potential Future Aquatic Receptors

Based on a screening of groundwater concentrations at Site 4 against brackish surface water screening levels, if groundwater contaminants from this site were to discharge to a surface water body without dilution or natural attenuation, aquatic receptors would potentially be at risk from pesticides (heptachlor, endrin, endosulfan II, 4,4'-DDT, methoxychlor, endrin ketone, and alpha-chlordane), explosives (2,4-DNT/2,6-DNT, 2,4,6-trinitrotoluene, amino-dinitrotoluenes, and RDX) and inorganics (aluminum, chromium, copper, iron, lead, manganese, nickel, and zinc).

Site 21 - Terrestrial Receptors

Based on a screening of soil concentrations against flora/fauna toxicity values, the terrestrial environment in Site 21 may be adversely impacted by soil concentrations of SVOCs, 4,4'-DDD, and inorganics (aluminum, cadmium, chromium, copper, iron, lead, manganese, mercury, thallium, vanadium, and zinc, and cyanide).

Conservative upper trophic level receptor models suggest that surface soil concentrations of inorganics (mainly aluminum, arsenic, cadmium, chromium, lead, mercury, and zinc), endrin, and di-n-butylphthalate produce HQ values above 1.0 for the american robin, american woodcock, and marsh wren. Inorganics (mainly aluminum, arsenic, cadmium, mercury, thallium, vanadium, and zinc), produced HQ values above 1.0 for the red fox, bob white quail, meadow vole, short tailed shrew, deer mouse, and red-tailed hawk.

Less conservative upper trophic level receptor models for Site 21 indicate potential risks to the red fox, american robin, meadow vole, short-tailed shrew, deer mouse, american woodcock, and marsh wren from surface soil concentrations of aluminum, cadmium, chromium, mercury, and zinc.

Site 21 - Potential Future Aquatic Receptors

Based on a screening of groundwater concentrations at Site 21 against brackish surface water screening levels, if groundwater contaminants from this site were to discharge to a surface water body without dilution or natural attenuation, aquatic receptors would potentially be at risk from heptachlor, aluminum, cadmium, chromium, cobalt, copper, iron, manganese, nickel, and zinc.

Site 22 - Terrestrial Receptors

Based on a screening of soil concentrations against flora/fauna toxicity values, the terrestrial environment in Site 22 potentially may be adversely impacted by soil concentrations of five SVOCs, 2,4,6-trinitrotoluene, HMX, amino-DNTs, RDX, 1,3,5-trinitrobenzene, and aluminum, cadmium, chromium, copper, iron, lead, silver, vanadium, zinc, and cyanide.

Conservative upper trophic level receptor models suggest that surface soil concentrations of aluminum, antimony, arsenic, cadmium, chromium, copper, lead, selenium, vanadium, and zinc produce HQ values above 1.0 for the red fox, bobwhite quail, american robin, meadow vole, short tailed shrew, deer mouse, american woodcock, marsh wren and red-tailed hawk.

Less conservative upper trophic level receptor models for Site 22 indicate potential risks to red fox, american robin, meadow vole, short tailed shrew, deer mouse, american woodcock, and marsh wren from surface soil concentrations of aluminum, arsenic, cadmium, chromium, copper, lead, selenium, vanadium and zinc.

Site 22 - Potential Future Aquatic Receptors

Based on a screening of groundwater concentrations at Site 22 against marine surface water screening levels, if groundwater contaminants from this site were to discharge to a surface water body without dilution or natural attenuation, aquatic receptors would potentially be at risk from the VOCs 1,1-dichloroethene and trichloroethene, the SVOC di-n-butylphthalate, the pesticide aldrin, explosives (HMX, RDX, tetryl) and metals (aluminum, iron, manganese, nickel, and zinc).

Sites 4, 21 and 22 - Freshwater Habitat - Aquatic Receptors

Based on a screening of surface water concentrations at Sites 4, 21 and 22- Freshwater Stations against fresh surface water screening levels, aquatic flora and fauna may be at a potential risk from 1,3-dinitrobenzene, 2,4-DNT/2,6-DNT, 2,4,6-trinitrotoluene, HMX, amino-DNTs, RDX, 1,3,5-trinitrobenzene, aluminum and iron. Based on a screening of freshwater sediment associated with Sites 4, 21 and 22 mercury may pose a potential risk to aquatic flora and fauna.

Conservative upper trophic level receptor models for freshwater stations suggest that surface water and/or sediment concentrations of benzo(a)pyrene, bis(2-ethylhexyl)phthalate, aluminum, antimony, arsenic, barium, and vanadium produce HQ values above 1.0 for the mink and the great blue heron.

Less conservative upper trophic level receptor models indicate potential risks to the mink and the great blue heron from surface water and/or sediment concentrations of benzo(a)pyrene, bis(2-ethylhexyl)phthalate, aluminum, and antimony.

Sites 4, 21 and 22 - Tidal Freshwater Habitat - Aquatic Receptors

Based on a screening of surface water concentrations at Sites 4, 21 and 22 - Tidal Freshwater Stations against tidal freshwater screening levels, aquatic flora and fauna may be at a potential risk from RDX, and aluminum, cadmium, iron, lead, and manganese. Based on a screening of sediment concentrations against sediment screening levels, aquatic flora and fauna may be at a potential risk from carbon disulfide and benzene, 4,4'-DDE, alpha- and gamma-chlordane, 2,4,6-trinitrotoluene, and aluminum, arsenic, barium, beryllium, cadmium, cobalt, copper, lead, manganese, mercury, nickel, selenium, silver, thallium, vanadium, and zinc).

Conservative upper trophic level receptor models for Sites 4, 21 and 22 - Tidal Freshwater Stations suggest that surface water and/or sediment concentrations of di-n-butylphthalate, aluminum, antimony, arsenic, barium, lead manganese, selenium, thallium and vanadium produce HQ values greater than 1.0 for the mink and the great blue heron.

Less conservative upper trophic level receptor indicate potential risks to aquatic receptors from surface water and/or sediment concentrations of aluminum, antimony, thallium, vanadium, and di-n-butylphthalate.

1.0 INTRODUCTION

This report presents the results of the Round Two Remedial Investigation (RI) completed for Sites 4 (Burning Pad Residue Landfill), 21 (Battery and Drum Disposal), and 22 (Burn Pad) at the U.S. Naval Weapons Station Yorktown (WPNSTA Yorktown), Yorktown, Virginia (Figure 1-1). This RI Report has been prepared by Baker Environmental, Inc. (Baker) under the Department of the Navy's (DoN's) Comprehensive Long-Term Environmental Action Navy (CLEAN) contract administered by the Naval Facilities Engineering Command, Atlantic Division (LANTDIV).

This RI Report has been prepared in accordance with the WPNSTA Yorktown Federal Facility Agreement (FFA), the Yorktown Master Work Plans (Baker, 1994a), and applicable Federal, Commonwealth, and local regulations. Details of the Round Two RI Scope of Work at Sites 4, 21 and 22 are contained in the Site-Specific Work Plan for Sites 4, 21 and 22 (Baker, 1996a). In addition, the United States Environmental Protection Agency's (USEPA's) document, Guidance for Conducting Remedial Investigations and Feasibility Studies Under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (USEPA, 1988) has been used as guidance for preparing this report. The RI Report has been prepared using available information from the previous investigations, such as the Round One RI effort (Baker/Weston, 1993a) and from data collected during the Round Two RI, which was conducted during October and November 1996.

The objectives of this report are: (1) to evaluate the results of the Round One RI effort and the Removal Action confirmation sampling conducted at Sites 4 and 21; (2) to assess the nature and extent of contamination at the sites and/or to identify data gaps preventing an adequate understanding of site conditions; and (3) to assess potential human health and ecological risks associated with any contamination remaining at the sites following the removal actions.

This document is organized into seven additional sections. Section 2.0 describes the field activities conducted during the Round Two RI at Sites 4, 21, and 22. This section describes the purpose of the study of individual media, sampling procedures, and sampling locations for all media. Figures are included to show sampling locations. This section also discusses quality control (QC) conducted during the sampling and the management of the investigation derived waste (IDW).

Section 3.0 presents the physical features of Sites 4, 21, and 22. This section discusses the general physiography (physical geography, surface water hydrology), geology, soil, hydrogeology, and land use and demography.

Section 4.0 presents the nature and extent of contamination found at Sites 4, 21, and 22. This section presents the results of the field sampling activities conducted as part of this RI. The results are presented by media: surface and subsurface soil, groundwater, surface water, sediment, and biota. This section also discusses the potential sources of contaminants detected during the sampling activities.

Section 5.0 characterizes the fate and transport of the contaminants found at Sites 4, 21, and 22. This characterization includes: potential routes of contaminant migration, contaminant persistence, and contaminant migration.

Sections 6.0 and 7.0 contain the baseline risk assessments (RAs) conducted for the sites. The baseline human health RA (Section 6.0) contains a human health evaluation and an environmental evaluation. An ecological RA is included in Section 7.0.

A summary and conclusions are presented in Section 8.0. This section summarizes the nature and extent of contamination, contaminant fate and transport, and potential human health and ecological impacts associated with the site.

1.1 Site History and Results of Previous Investigations

The information in this section has been drawn from the Site Management Plan (Baker, 1996b), the Round One RI Report (Baker/Weston, 1993a), the Summary of Background Constituent Concentrations and Characterizations of the Biotic Community for the York River Drainage Basin (Baker, 1995b), the Final Closeout Report for Sites 4, 16, and 21 (IT, 1995), and Final Master Project Plans (Baker, 1994a).

1.2 Sites 4, 21, and 22-Description and History

Fifteen sites requiring RI/Feasibility Study (FS) activities are identified in the Fiscal Year 1996-1997 Site Management Plan (SMP) for WPNSTA Yorktown (Baker, 1996b). The locations of Sites 4, 21, and 22 within the Station are presented on Figure 1-2. Figure 1-3 shows more topographic details of the sites, and Figure 1-4 presents aerial photograph of the sites. The following subsections provide site-specific information for Sites 4, 21, and 22 and information on previous investigations.

1.2.1 Site 4 - Burning Pad Residue Landfill

Site 4, the Burning Pad Residue Landfill, consists of over 10 acres. As shown on Figures 1-3 and 1-16, the site is bordered by the Explosives Burning Facility 1401 (Site 22) to the southwest, Site 21 (the Battery and Drum Disposal Area) and an unnamed drainage way to the southeast, West Road to the northeast, and a gravel road leading to the burning facility to the northwest.

Site 4 was used as a disposal area between 1940 and approximately 1975. Reportedly, the landfill was a ravine in which trench and fill operations took place. The landfill area was reportedly backfilled three to four times a week (C.C. Johnson, 1984). An ash pile measuring approximately 100 feet by 150 feet was located in the northeast corner of the site.

Materials reportedly disposed at Site 4 included: carbon-zinc batteries from underwater weapons; burning pad residues (possibly containing aluminum, cyclotrimethylene trinitroamine [RDX], TNT, 2,4-dinitrotoluene [2,4-DNT], and cyclotetramethylenetetranitramine [HMX]); tree stumps; fly ash from coal-fired boilers; mine casings; electrical equipment (possibly telephone poles, line hardware, etc.); and transformers (possibly containing polychlorinated biphenyl [PCB] oils). The landfill received an estimated 17 tons of waste per year (C.C. Johnson, 1984). The depth of fill in the main fill area was estimated from a geophysical study to be approximately 5 to 10 feet.

An investigation of subsurface source areas, conducted by IT Corporation (IT) in December 1992, identified a large battery disposal area located in the southeast part of the site. The batteries were found between 2 and 4 feet below ground surface (bgs). Additional landfill material consisting of construction debris, scrap metal, piping, glass, concrete, bottles, cans, and drums, was also identified at various locations within the site boundary.

In 1994, IT conducted a Removal Action at the site to dispose of the surface debris and the battery disposal areas. Materials were removed from several areas throughout the site. One of these areas included the area around an ash pile located in the northeast corner of the site near West Road.

The majority of the site is relatively open, with scrub grasses and small trees; larger trees are present in the northern and southeastern portions of the site. A gravel road now loops through the site and meets West Road. A dirt or gravel road formerly cut through the site and led towards Site 22. The topography within the open area of Site 4 is relatively flat with elevations ranging between 33 to 47 feet above mean sea level (msl). In the wooded areas along the southeastern portion of the site, the topography slopes sharply down towards the unnamed drainage way with elevations changing from 39 to less than 10 feet above msl.

1.2.2 Site 21 - Battery and Drum Disposal Area

Site 21, the Battery and Drum Disposal Area, is a small wooded area covering approximately 1-acre. The site is located immediately adjacent to the unnamed drainage way leading to Felgates Creek. West Road is located southwest of the site, and Site 4 is to the northwest (Figures 1-3 and 1-17).

Site 21 was identified in November 1990 by WPNSTA Yorktown personnel and, therefore, had not been included in any previous investigations. Wastes noted and confirmed during a reconnaissance of Site 21 in October 1991 by Roy F. Weston, Inc. (WESTON) personnel included: various sized drums; batteries (Leclanche type); empty solvent containers; and scrap metal. Waste was noted throughout the site area with several areas of concentrated waste dumping (batteries and drums) noted. Based on a geophysical investigation, the fill area was estimated to be approximately 200 feet by 200 feet, with apparently well-defined boundaries (Baker, 1993).

Site 21 was investigated as part of a subsurface soil study performed by IT in December 1992. This investigation indicated the presence of approximately 5 to 8 inches of topsoil under which batteries were present at thicknesses of 2 to 6 feet. The batteries were a carbon-zinc dry chemistry type, consistent with the type observed on the surface.

In 1994, IT performed a Removal Action at the site designed to remove identified wastes. Wastes were removed, in various quantities as discussed later in this report, from the majority of the site.

The site has been cleared in the area of the Removal Action. Small and large trees surround the removal action area and make up the remaining area of the site (based on a March 12, 1993 aerial photograph, the site was entirely covered with small and large trees prior to the removal action). A dirt road extending from West Road leads to the removal action area. The topography within the site is relatively steep; it falls sharply towards the on-site drainage way located along the western and southeastern portions of the site. Site elevations range from 5 to 45 feet above msl.

1.2.3 Site 22 - Burn Pad

Site 22 is located south of Site 4 and west of Site 21 (Figure 1-3). A circular array of 11 steel burning pans was used for burning waste plastic explosives and spent solvents. The pans surround a 150-foot diameter circular area. Open burning operations at the Burn pad ceased in 1994. Site 22 was used for a treatability large scale study (TS) for the treatment of nitramine-contaminated soil and treatment area for TNT-contaminated soil. A 153-foot by 86-foot biocell (Figure 1-18) was constructed at this site. Biocell operations ceased in 1998 and treated (clean) soil was pumped into an impoundment area which was established in the topographical low area located directly to the southeast of the existing biocell. This area served to dewater clean treated soil. In 1999, Site 22 received maintenance to prevent erosion to the wetlands located to the west of the biocell. An earthen dam built to hold clean soil and water in the impoundment area was also opened to prevent rainwater from overflowing into Felgates Creek.

1.3 Results of Previous Investigations

Previous investigation reports completed through the IRP include the following:

- Initial Assessment Study (IAS) (C. C. Johnson & Associates, Inc., 1984)
- Confirmation Study (CS) Rounds One and Two Reports (Dames and Moore, 1986 and Dames and Moore, 1988)
- RI Interim Report (Versar, 1991)

- Site Inspection of Site 21 (WESTON, 1992)
- Round One RI Report (Baker/WESTON, 1993a)
- Focused Biological Sampling and Preliminary Risk Evaluation Report (Baker/WESTON, 1993b)
- Habitat Evaluation Report (Baker, 1994b)
- Removal Action at Sites 4 and 21 (IT, 1995)

These reports have been generated in conjunction with the continuing development of the DoD IRP. Summaries of previous investigations are provided in the following subsections.

1.3.1 Initial Assessment Study

The purpose of the IAS (C. C. Johnson & Associates, Inc. and CH2M Hill, July 1984) was to identify and assess sites posing a potential threat to human health and/or the environment due to contamination from past operations. A total of 19 potentially contaminated sites were identified based on information from historical records, aerial photographs, field inspections, and personnel interviews. Each site was evaluated for the type of contamination, migration pathways, and potential receptors present. The IAS concluded that 15 of the 19 sites, including Site 4, were of sufficient threat to human health or the environment to warrant Confirmation Studies (CSs).

In the IAS, a CS was recommended for Site 4 based on the reported presence of hazardous materials and the potential for surface and groundwater contamination at the site. The IAS recommended the following activities to be conducted for the CS: (1) installation of five monitoring wells located around the suspected disposal areas; (2) collection of groundwater samples from the wells; and (3) collection of surface water and sediment samples from two locations in Felgates Creek (C.C. Johnson, 1984).

Sites 21 and 22 had not been identified as potentially contaminated areas at the time of the IAS.

1.3.2 Confirmation Studies

Two rounds of data were obtained during the CS effort. The first round of sampling and analysis was documented in the "Confirmation Study Step IA (Verification), Round One" (Dames & Moore, 1986). The results of the second round of sampling and comparisons with appropriate regulatory standards were presented in the Confirmation Study Step IA (Verification, Round Two" [Dames & Moore, 1988]).

Round One CS activities at Site 4 included the installation and sampling of five groundwater monitoring wells and the collection and analysis of two surface water/sediment samples (as recommended in the IAS). The analyses performed on the samples included priority pollutants, explosives, inorganics, and various other parameters (Dames & Moore, 1986). Monitoring wells installed at Site 4 during the CS are still in existence and were incorporated into the groundwater monitoring network for the Round Two RI at this site.

Based on the results of the Round One CS, the Dames & Moore report recommended the following Round Two CS sampling and analysis actions for Site 4: (1) combine the upstream surface water/sediment station for Site 4 with that for Site 8 (another IRP site located nearby); and (2) confirm the previous analyses for all of the sampling stations from Round One.

The Round Two CS was conducted during November and December, 1987 (Dames & Moore, 1988). Round Two CS activities at Site 4 included sampling of the five existing groundwater monitoring wells and the collection and analysis of two surface water/sediment samples (as recommended in the Round One CS). The analyses included priority pollutants, explosives, inorganics, and a few other parameters. No recommendations for Site 4 were presented in the Round Two CS (note that Sites 21 and 22 were not yet identified).

1.3.3 Interim Remedial Investigation

An Interim RI Report (Draft) was originally prepared by Dames & Moore in February, 1989 and later amended by Versar, Inc. in July 1991. The RI Report marked the conversion between the two Navy programs, the Navy Assessment and Control of Installation Pollutants (NACIP) and the IRP, which culminated in the preparation of the Interim RI Report. The purpose of the report was to

summarize the existing data for each site and provide recommendations for additional efforts to complete the RI (Versar, 1991).

The Interim RI Report recommended additional investigatory efforts and a risk assessment for 14 of the 15 sites included under the CS. Site 4 was one of the 14 sites where further investigations were recommended. (Note that Sites 21 and 22 were not yet identified.)

1.3.4 Site Inspection of Site 21

As previously mentioned, Site 21 was not identified as a site until November 1990, and therefore, had not been included in the previous IAS, CSs, or Interim RI. WESTON conducted an SI at Site 21 in October 1991. The objective of the SI was to assess if contamination was present at Site 21 due to past disposal practices (WESTON, 1992).

As part of this study, three monitoring wells were installed and sampled, along with the collection of surface and subsurface soil samples. The groundwater samples were analyzed for Target Compound List (TCL) volatile organic compounds (VOCs) and semivolatile organic compounds (SVOCs), total petroleum hydrocarbons (TPH), and Target Analyte List (TAL) inorganics (total and dissolved). Soil samples were collected from both the surface (0- to 6-inches) and the subsurface (selected zones within 0- to 24-feet), and analyzed for TCL VOCs and SVOCs, TPH, and TAL inorganics.

The outcome of this investigation was presented in the report entitled "Draft Final Site Inspection Report Site 21-Battery and Drum Disposal Area Naval Weapons Station Yorktown, Virginia" February 5, 1992. The results are briefly summarized below (WESTON, 1992).

- The detection of TPH in all three wells indicated a possible fuel-related source.
- Cadmium and zinc levels in the groundwater indicated potential leaching of battery fluids at the site.
- Additional investigation of the groundwater directly downgradient of Site 21 is required to determine whether contamination has been released from the site.

- SVOCs (commonly associated with burned residue, creosote, fuel-related material, and similar substances) were detected in the down-slope surface soil samples. The exact source of the SVOCs was not identified.
- The inorganic results from the surface soil samples suggest that leaching of metals from batteries and other metal-containing material may have occurred at the site.
- The majority of inorganics (e.g., cadmium and zinc) in subsurface soil were detected at higher concentrations in the down-slope soil samples than in the up-slope samples, suggesting an impact from disposal activities at the site.

1.3.5 Round One Remedial Investigation

A Round One RI was conducted from June 1, 1992 to October 30, 1992 at 16 sites (including Sites 4 and 21, but not at Site 22) within WPNSTA Yorktown. This Round One RI was based on the recommendations from the Interim RI and from the Site 21 SI. The objectives of the Round One RI Program were to: (1) assess the nature and extent of contamination at the 16 sites; (2) collect sufficient information to identify potential migration pathways and, as part of the RA to be performed, to forecast resulting impacts on animal, plant, and human populations, with a special emphasis on the impacts upon ecological resources, and to assess the risk to human health and the environment; (3) obtain data for the FS which includes development of specific remedial action alternatives; and (4) provide a basis for classifying the sites according to the potential severity of known or potential environmental impacts in order to proceed with expedient actions, as appropriate (WESTON, 1993a).

All of the data generated during the Round One RI were submitted for third party data validation. Validation of the analytical data, through established procedures, served to reduce the inherent uncertainties associated with its usability.

This subsection presents the results of the laboratory analysis performed on samples collected as part of the soil, groundwater, surface water, and sediment investigations (refer to Figure 1-5 through 1-13).

1.3.5.1 Site 4 Round One RI

The data from the Site 4 Round One RI is summarized, by medium, in the following subsections.

Surface Soil Sampling Results-Round One

During the Round One RI, six surface soil samples (4S01-001 through 4S06-001 provided on Figure 1-5) were collected from the 0- to 2-foot interval and analyzed for TCL VOCs, TCL SVOCs, PCB compounds, and TAL inorganics using Contract Laboratory Program (CLP) protocols and Level D data quality. In addition, several samples underwent analyses for TPH and explosive constituents. Select organic constituents along with concentrations detected in surface soil samples are presented on Figure 1-6. Select inorganic constituents detected in surface soil samples are provided on Figure 1-7. A summary of the results is presented below.

The surface soil at Site 4 contained various contaminants, namely SVOCs, PCBs, and explosives. However, Site 4 is primarily contaminated with polynuclear aromatic hydrocarbons (PAHs) as a result of asphalt, roofing paper, and burn debris (i.e., wood). In addition, some areas contained elevated concentrations of inorganic constituents which may be attributed to past waste management activities (i.e., copper, lead, and zinc from battery disposal).

Site 4 Groundwater Sample Results-Round One

During the Round One RI, five groundwater samples were collected (4GW01-001 through 4GW05-001 provided on Figure 1-8) and analyzed for TCL VOCs, TCL SVOCs, TCL PCB compounds, and TAL inorganics (total and dissolved) using CLP protocols and Level D data quality. In addition, several samples underwent analyses for explosive constituents. Selected organic constituents detected in the groundwater samples are presented on Figure 1-8. All of the inorganic results for the Round One RI groundwater samples are provided on Table 1-1. A summary of the results is presented below.

In groundwater, positive detections of VOCs were primarily limited to samples collected downgradient of Site 4. The concentration of trichloroethene (TCE) in two wells (46W04 and 4GW05) exceeded the Federal Maximum Contaminant Level (MCL) of 5.0 µg/L. SVOCs or PCBs

were not detected in any of the groundwater samples. Several explosive constituents were also detected in groundwater; the highest concentrations were detected in the downgradient well nearest to the site. Inorganic constituents were the most prevalent among potential contaminants in groundwater at Site 4 and were found distributed throughout the site. Several unfiltered (total) inorganics (cadmium, chromium, lead, and zinc) were found consistently above Virginia Groundwater Standards (VGS) or Federal MCLs; dissolved (filtered) inorganics were significantly less.

Site 4 Surface Water/Sediment Results-Round One

Five surface water and sediment samples were collected from Site 4 (4SW/SD02 through 4SW/SD06 provided on Figure 1-5) and analyzed for TCL organics (excluding pesticides), TAL inorganics (total and dissolved), hardness, and explosive constituents. Sediment samples were also analyzed for pH and total organic carbon (TOC).

The surface water samples associated with Site 4, which were collected from the tributary to the eastern branch of Felgates Creek and Felgates Creek itself, served to characterize the off-site impacts from Site 4 (which also represents Site 21). Select organic constituents detected in the surface water samples are also provided on Figure 1-9; inorganic constituents are provided on Table 1-2.

Sediment samples were collected from two intervals (the 0- to 6-inches interval and the 6- to 12-inches interval) at the locations presented on Figure 1-5. Select organic constituents detected in the sediment samples are presented on Figure 1-10; inorganic constituents are provided on Table 1-3. It should be noted that the numbering system for surface water/sediment sampling started with 4SW/SD02 and did not include a location for 4SW/SD01, as it is suspected that this location was combined with 8SW/SD01 for Site 8. A summary of the surface water/sediment results is provided below.

The surface water and sediment at Site 4 is primarily impacted by the presence of elevated inorganic constituents. In addition, several surface water samples contained varying concentrations of explosive compounds. Several sediment samples contained pesticides at low concentrations. Therefore, based on the discussed results, the surface water and sediment at Site 4 appear to have been impacted by past site operation activities.

1.3.5.2 Site 21 Round One RI

The data from the Site 21 Round One RI is summarized, by media, in the following subsections.

Site 21 Surface Soil Results-Round One

During the Round One RI, ten surface soil samples (21S05-001 through 21S14-001 provided on Figure 1-11) were collected from the 0- to 2-foot interval. Soil samples collected at Site 21 were analyzed for TCL VOCs, TCL SVOCs, and TAL inorganics using CLP protocols and Level D data quality. In addition, several samples underwent analyses for TPH constituents. Selected organic and inorganic constituents detected in the surface soil samples are presented on Figure 1-11 and 1-12, respectively. The results of the Round One RI are summarized below.

The surface soil at Site 21 contained various organic contaminants (e.g., VOCs and SVOCs) and inorganic contaminants (e.g., cadmium, mercury, and zinc). These contaminants appear to be the result of previous site activities.

Site 21 Subsurface Soil Results-Round One

Drilling activities as part of the Round One effort included one soil boring at Site 21, which was converted into a monitoring well. Only one soil sample (21SB04-001) and a duplicate (21SB04-101) were able to be collected from the boring due to the shallow depth of the groundwater. The sample was analyzed for TCL organics, TAL inorganics, pH and TPH using CLP protocols and Level D data quality. Selected organic and inorganic constituents detected in subsurface soil samples are presented on Figure 1-13. The results of the Round One RI are summarized below.

The VOCs, methylene chloride, acetone, toluene, and the SVOC phenol were detected in the duplicate of the subsurface soil sample. However, methylene chloride, acetone, and toluene are common laboratory contaminants and may not be attributable to past site activities. The concentrations of inorganics detected in the subsurface soil samples were comparable to those found in background samples collected as part of the Round One RI.

Site 21 Groundwater Sampling Results-Round One

Four groundwater samples (21GW01 through 21GW04) were collected at Site 21 (three from existing wells and one from a newly-installed well) to confirm the presence or absence of contaminants and evaluate overall groundwater chemistry. Groundwater sampling was performed in accordance with USEPA guidelines. The samples were analyzed for TCL VOCs and SVOCs, TAL inorganics (total and dissolved), nitrates, and TPH constituents. There were no organic constituents detected in the groundwater samples. This is presented on Figure 1-8; inorganic constituents are provided on Table 1-4. The results of the groundwater sampling program are summarized below.

Inorganic constituents were the most prevalent among potential groundwater contaminants at Site 21 and were found to be distributed throughout the site. Several unfiltered (total) inorganics (beryllium, cadmium, chromium, lead, and zinc) were found consistently above VGS or Federal MCLs; however, dissolved (filtered) inorganics were significantly less. Based on the discussed results, the soil and groundwater at Site 21 appears to have been impacted by past site operation activities.

1.3.6 Focused Biological Sampling and Preliminary Risk Evaluation Report

A biological sampling project was conducted in October of 1992, which included limited biological tissue, surface water, and sediment sampling. The primary objective of the sampling program was to evaluate the potential human health risk associated with consumption of fish and shellfish taken from select waters within WPNSTA Yorktown, including Felgates Creek, which is adjacent to Sites 4, 21, and 22. These efforts were summarized in the Focused Biological Sampling and Preliminary Risk Evaluation Report (Baker/WESTON, 1993b).

1.3.7 Habitat Evaluation Results

The Habitat Evaluation results (Baker, 1994b) are presented in two subsections; aquatic habitats which discuss the stream areas and terrestrial habitats which discuss the land areas. Sites 4, 21, and 22 (though not discussed specifically in this report) are located in the watershed of Felgates Creek.

1.3.7.1 Site 4 Habitat Evaluation Results

The results of the aquatic and terrestrial habitat evaluations for Site 4 are presented below.

Aquatic Habitats

No sources of surface water were associated with this site. A stream channel at Site 21, which also provides drainage for Site 4, is described in Section 2.2.7.2.

Terrestrial Habitats

Three general habitat types were identified at Site 4. These included an open field, scrub shrub/mixed forest edge and upland forest. Generally, the open field was surrounded by edge habitat; this edge habitat also occurred between Site 4 and the burn pad area. Some upland forest was present between Site 4 and Site 21. Because of the mix of habitats present at Site 4, a number of birds were identified during the field study. Turtle eggs that had been excavated and eaten were found at Site 4. White-tailed deer and squirrels were also observed during the site visit.

1.3.7.2 Site 21 Habitat Evaluation Results

The results of the aquatic and terrestrial habitat evaluations for Site 21 are presented below.

Aquatic Habitats

Aquatic habitats associated with Site 21 included one small stream. The west side of Site 21 slopes steeply to the southwest and makes up the headwaters to an unnamed tributary to Felgates Creek. The stream drained both Site 4 and Site 21 and is located between the two sites. Two intermittent channels (no flow or macroinvertebrates were observed during the time of this evaluation), both linear and steep in slope, led to the stream channel and drained Site 21. Flowing water was present near the outlets but was too low in volume to support fish. Seep areas were observed along the stream banks, many of which were red/orange stained. The ravine basin was composed of both muck and sand; crayfish burrows were observed within and adjacent to the stream channel from its headwaters to its confluence with Felgates Creek.

Terrestrial Habitats

Two terrestrial habitats were present at Site 21. Upland forest was present in the general area. This upland forest had been replaced by a mixed forest over the disposal area. In fact, the general disposal area could almost be delineated by the difference in vegetation. Several common birds were observed and a box turtle was found at Site 21 during the field study. In addition, signs of several mammals were observed, including white-tailed deer, grey squirrel, striped skunk, raccoon, and fox.

1.3.8 Removal Actions

IT conducted a Removal Action at Sites 4 and 21 in the fall/winter of 1994. As part of the Removal Action, confirmation surface soil sampling was performed during the Post-Removal Action Activities. The results of the Post-Removal Action will be discussed in greater detail in Section 4.0 of this report where the results will be used in conjunction with the risk assessment. A brief summary is presented in the paragraphs that follow.

Surface soil samples were assessed for contamination following the Removal Action at Sites 4 and 21. These data were evaluated prior to placement of topsoil and revegetation of the disturbed areas. The sampling program consisted of collecting a total of 55 surface soil (0- to 6-inches) samples (43 from Site 4 and 12 from Site 21) and six subsurface soil (6- to 18-inches) samples from Site 21. Each sample was analyzed for TCL organics, TOC, TPH, and nitroexplosives. Confirmatory sample results were received in CLP data packages which underwent third party data validation.

Site 4 Surface Soil Results-Removal Action

A total of 42 surface soil samples were collected at Site 4 as part of the post removal action/confirmation sampling efforts. Figure 1-14 depicts surface soil sample locations. Additional discussion regarding detected organic and inorganic constituents will be provided in Section 4.0.

Results from post removal action/confirmation sampling indicated the following:

- Twenty surface soil samples contained VOCs at trace amounts. All of the VOCs detected, but one, are considered common laboratory contaminants including

methylene chloride, acetone, 2-butanone, and toluene. Trichloroethene was detected at a concentration of 8J µg/kg.

- Forty surface soil samples contained SVOCs with the highest concentrations found in the western and southwest portions of Site 4. A total of 24 different SVOCs were detected in soil samples collected from Site 4. Twenty-two of the samples collected contained total PAHs at concentrations greater than 1000 µg/kg. The high concentrations of PAHs may be attributable to the presence of asphalt, roofing tar, burnt wood, and other types of construction debris which was either present in the location of the soil sample or placed in the sample container.
- Twenty-two surface soil samples contained pesticides at concentrations indicative of controlled applications. A total of 13 organic pesticide compounds were detected in soil samples collected from Site 4. In general, pesticide concentrations were limited to areas along roadways with little to no pesticides found in the wooded areas. 4,4'-DDT and its metabolites were the most prevalent pesticides found. Total pesticide concentrations ranged from 2.46 µg/kg to 291 µg/kg. It should be noted that pesticides have been detected Station wide and; therefore, are not believed to be site-related.
- Eight surface soil samples contained PCBs at concentrations below 1.0 mg/kg. The primary PCBs detected included Aroclor-1254 and Aroclor-1260.
- Explosive constituents were detected in three samples collected in the northeastern portion of Site 4 at total concentrations of 15 mg/kg, 60 mg/kg, and 99 mg/kg. HMX, RDX, and 2,4,6-trinitrotoluene were the primary explosive constituents detected.
- Twenty-two inorganic constituents were detected in all 42 samples at varying concentrations..

Site 21 Surface Soil Results-Removal Action

The locations of the 12 surface soil samples collected as part of the post removal action sampling are shown on Figure 1-15. Additional summaries for organic and inorganic constituents will be provided and discussed in Section 4.0.

Results from post removal action sampling indicated the following:

- Five surface soil samples contained VOCs at trace amounts. All of the VOCs detected are considered common laboratory contaminants including methylene chloride and toluene. No other VOCs were detected.
- Ten surface soil samples contained SVOCs with the highest concentrations found outside of the excavation area in the southwest portion of Site 21. The primary SVOCs detected were PAHs located within the woods. Several other areas contained SVOCs; however, the variations and concentrations were significantly less.
- Six surface soil samples contained trace amounts of pesticides indicative of controlled applications which were performed Station wide. Total pesticide concentrations were all less than 1,000 µg/kg.
- PCBs or explosives were not detected in surface soil.
- Inorganics like aluminum, lead, and zinc were detected in all twelve soil samples at varying concentrations.

Site 21 Subsurface Soil Results-Removal Action

Post Removal Action sampling was performed subsequent to excavation activities at Site 21. These samples have been designated as subsurface as the excavated areas of Site 21 have been backfilled with clean fill and regraded. The locations of the six subsurface soil samples collected as part of the

post removal action sampling are shown on Figure 1-15. Additional discussion regarding detected organic and inorganic constituents will be provided in Section 4.0.

Results from post removal action subsurface soil sampling indicated the following:

- Three subsurface soil samples contained VOCs at trace amounts. The VOCs detected are common laboratory contaminants including methylene chloride and toluene. No other VOCs were detected.
- Five subsurface soil samples contained SVOCs with the highest concentrations detected in the southern portion of Site 21. The primary SVOCs detected were PAHs; however, the levels at which they were detected are several times below those detected in samples collected outside of the Site 21 boundary.
- Two subsurface soil samples contained pesticides with total concentrations less than 1,000 µg/kg. The pesticides detected and their corresponding concentrations were indicative of controlled applications and not related to site operations.
- One sample contained the PCB Aroclor-1260 at a concentration of 32J µg/kg. This subsurface soil sample is located in the southern portion of the site.
- Explosives were not detected in subsurface soil samples.
- Inorganic constituents were detected in all six subsurface soil samples at varying concentrations. Many of the inorganic constituents detected were at similar concentrations or less than those detected in surface soil.

Following the removal actions, the sites were regraded and revegetated. A biocell for biotreatment of explosives-contaminated soil was constructed at Site 22. Aerial photographs depicting post-removal conditions at the sites are included on Figures 1-16, 1-17, and 1-18.

1.4 References

Baker Environmental, Inc. (Baker). 1995a. Final Site Management Plan for Fiscal Years 1995-1996, Naval Weapons Station Yorktown, Yorktown, Virginia. February 1995.

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2.0 STUDY AREA INVESTIGATION

This section describes the Round Two field sampling activities conducted during the RI at Sites 4, 21, and 22. The objectives of the study, individual media investigated, sampling procedures, and sampling locations are discussed. This section also discusses Quality Control (QC) procedures conducted during the sampling as well as management of the Investigation Derived Waste (IDW).

2.1 Introduction

The Round Two field program at Sites 4, 21, and 22 was designed to provide information necessary to characterize potential human health effects and ecological impacts resulting from previous site activities. The following subsections present the sites and RI/FS objectives that were used in the human health and ecological risk assessments (RAs) for each site.

The Round One RI data for Sites 4 and 21 indicated potential contamination in surface soil, groundwater, surface water, and sediment; however, the available data were not sufficient to fully define the degree of contamination. Furthermore, Round One RI surface soil samples were collected from the 0- to 2-foot interval which is contradictory to current risk assessment practice at WPNSTA Yorktown, which identifies samples collected from the 0- to 6-inch interval as surface soil samples. The Removal Action data also indicated potential contamination in the surface soil at Site 4 (primarily SVOCs, pesticides/PCBs, and inorganics) and Site 21 (primarily SVOCs and inorganics).

The groundwater results presented during the Round One RI for Site 4 indicated the presence of VOCs, explosives, and inorganics, with the highest concentrations located in the downgradient well nearest to the site. The Round One RI groundwater results for Site 21 indicated the presence of inorganics, which were found to be distributed throughout the site.

Subsurface soil samples collected during the Removal Action at Site 21 indicated elevated levels of SVOCs and inorganics and one positive detection of Aroclor-1260.

Aquatic ecological investigations were not conducted during the Round One RI. To collect information necessary for developing the Ecological Risk Assessment (ERA), the field investigation included tasks to determine the extent of contamination in the surface water/sediment, and to provide data for human health and ecological risk assessments.

Analytical data obtained during this investigation was compared to the most recent USEPA Region III RBC Table for the human health risk assessment. For the ecological risk assessment, analytical data was compared to USEPA Region III Biological Technical Assistance Group (BTAG) screening levels (August 1995). The objectives for this RI/FS conducted at the three sites are presented on Table 2-1.

2.2 Round Two Field Sampling Program

The field investigation at Sites 4, 21, and 22 commenced in August 1996 with the collection of surface water, sediment, and biota samples within the eastern branch of Felgates Creek. The field investigation was continued in late October 1996 and was completed in mid November 1996 with the collection of surface, subsurface soil, and groundwater samples and the installation of groundwater monitoring wells. These activities are outlined in the following subsections.

2.2.1 Soil Investigation

The soil investigation for Sites 4, 21, and 22 included the collection of both surface and subsurface soil samples in accordance with the Final Work Plan for Sites 4, 21, and 22 (Baker, 1996). Surface soil samples were collected with stainless-steel spoons and aluminum pie pans, and subsurface soil samples were collected with a drill rig (split-spoon sampler) during the advancement of soil borings and the installation of monitoring wells. A summary of the surface soil sampling program at Sites 4, 21, and 22, including sampling locations, the sampling date, and analytical parameters is provided in Table 2-2. Table 2-3 provides similar information for subsurface soils. Surface and subsurface soil sampling locations are presented in Figures 2-1 through 2-4.

2.2.1.1 Surface Soil Sampling

The following subsections present surface soil sampling for all three of the sites.

Site 4 - Surface Soil

At Site 4, nine surface (0- to 6-inch bgs) soil samples (4SS43 through 4SS50, plus one duplicate) were collected at the eastern portion of the site near the former ash pile and at the northwestern portion of the site. These samples were collected to fill data gaps from the post removal confirmation sampling performed by IT Corp. The surface soil sample locations (including the surface soil samples collected by IT Corp.) are presented on Figure 2-1. The surface soil was collected using stainless-steel sampling spoons; aluminum pie pans were used to composite the soil. The first inch of grass, matted roots, and/or humus material was removed prior to sample collection. The samples were placed in the appropriate containers and submitted for laboratory analysis. The samples were prepared according to USEPA Region III SOPs, Section 3.8 of the Final Master FSP (Baker, 1994a), and Section 4.1.1, and 4.2.1 of the Final Work Plan for Sites 4, 21, and 22 (Baker, 1996).

The surface soil samples were analyzed for TCL semivolatile organics, nitramine compounds, pesticides/PCBs, TAL inorganics, total organic carbon (TOC), and nitrate/nitrite, and select samples were analyzed for cation exchange capacity (CEC). Table 2-2 summarizes the analytical program for surface soil investigation.

Site 21- Surface Soil

At Site 21, five surface (0- to 6-inch bgs) soil samples (21SS19 through 21SS22, plus one duplicate) were collected from the western and southern portion of the site along the northeast boundary of the marsh area that encompasses the small unnamed tributary that leads to the east branch of Felgates Creek as shown on Figure 2-2. The samples were collected to obtain information to be used in the baseline RA and the ERA, and to be included with the surface soil sample data from the removal action (IT, 1994) for determining the extent of surface soil contamination at the site. The surface soil samples were collected using stainless-steel sampling spoons; aluminum pie pans were used to composite the soil. The first inch of grass, matted roots, and/or humus material was removed prior to sample collection. The samples were placed in the appropriate containers and submitted for laboratory analysis. The samples were prepared according to USEPA Region III SOPs, Section 3.8 of the Final Master FSP (Baker, 1994a), and Section 4.1.1, and 4.2.1 of the Final Work Plan for Sites 4, 21, and 22 (Baker, 1996).

The surface soil samples were analyzed for TCL semivolatile organics, pesticides/PCBs, TAL inorganics, total organic carbon (TOC), and nitrate/nitrite. Table 2-2 summarizes the analytical program for surface soil investigation.

Site 22- Surface Soil

Twenty-six surface (0- to 6-inch bgs) soil samples (22SS01 through 22SS23, plus three duplicates) were collected at Site 22. Surface soil samples 22SS01 through 22SS20 were collected in September 1996 from the main portion (circular burning facility area) of the site before the construction of the biocell. The remaining surface soil samples were collected in late October 1996 (beginning of the field investigation for the site) at the eastern portion of the site adjacent to the march area that encompasses the small unnamed tributary that leads to the east branch of Felgates Creek. Figure 2-3 presents the surface soil sample locations. The samples were collected to obtain information to be used in the baseline RA and the ERA, and to determine the extent of surface soil contamination at the site. The surface soil samples were collected using stainless-steel sampling spoons; aluminum pie pans were used to composite the soil. The first inch of grass, matted roots, and /or humus material were removed prior to sample collection. The samples were placed in the appropriate containers and submitted for laboratory analysis. The samples were prepared according to USEPA Region III SOPs, Section 3.8 of the Final Master FSP (Baker, 1994a), and Section 4.1.1, and 4.2.1 of the Final Work Plan for Sites 4, 21, and 22 (Baker, 1996).

The surface soil samples were analyzed for TCL semivolatile organics, pesticides/PCBs, nitramine compounds, TAL inorganics, total TOC, ammonia, nitrate/nitrite, and TKN. In addition, one sample was analyzed for CEC. Table 2-2 summarizes the analytical program for surface soil investigation.

2.2.1.2 Soil Borings and Subsurface Soil Sampling

Site 4

Seven subsurface (deeper than 6-inches bgs) soil samples were collected from three soil borings (4SB/GW06A, 4SB07 and 4SB08) to evaluate the horizontal and vertical extent of potentially impacted soil and for the RA evaluation purposes. The soil borings were located at the northwest

portion of the site (4SB07), at the center (4SB/GW06A) and south of the site (4SB08) as presented on Figure 2-4.

Two of the soil borings, 4SB07 and 4SB08, were utilized for subsurface soil sampling and for exploration purposes. These borings were advanced to depths of 60-ft below ground surface (bgs). Descriptions of the lithology from split-spoon samples indicate that groundwater was encountered at 26- to 32-ft bgs.

From each of these three borings, two subsurface soil samples were collected; one from the approximate mid-point of the boring, and one from just above the top of the water table. In addition to environmental sampling, four samples were collected to access the fate and transport of contaminants. Two of the samples were collected just above the groundwater table and two were collected below the groundwater table (within the screened interval of monitoring wells). The sampling protocols were described in Section 3.9 of the Final Master FSP (Baker, 1994a) and Sections 4.1.1 and 4.2.1 of the Final Work Plan for Sites 4, 21, and 22 (Baker, 1996).

The environmental subsurface soil samples were analyzed for TCL volatile organics, TCL semivolatile organics, nitramine compounds, pesticides/PCBs, TAL inorganics, TOC, and nitrate/nitrite. The samples collected to access the fate and transport of contaminants were analyzed for CEC, grain size, pH, and bulk density. Table 2-3 summarizes the analytical program for subsurface soil investigation.

In addition, five soil borings were advanced at the site to install monitoring wells for groundwater sampling. Two of the soil borings (4BS/GW06 and 4BS/GW01A) were advanced for the installation of shallow (37- to 50.5-ft bgs) monitoring wells, and three of the borings (4BS/GW02A, 4BS/GW05A, and 4BS/GW06A) were advanced for the installation of deep (65- to 80.5-ft bgs) monitoring wells. All soil borings, whether or not they were sampled for chemical analysis, were advanced using a split-spoon sampler and hollow-stem augers. Standard operating procedures (SOPs) for soil boring advancement and subsurface soil sampling are presented in the Final Master FSP (Baker, 1994a) and Section 4.1.1 of the site specific work plan for the site.

Each split-spoon sample was classified visually by the on-site geologist. Lithological descriptions of the soil are provided on the Test Boring Records and Well Construction Records in Appendix A.

Specific sampling and soil classification procedures are outlined in Sections 4.1.1 and 4.2.1 of the Final Work Plan for Sites 4, 21, and 22 (Baker, 1996) and Section 3.9 of the Final Master FSP (Baker, 1994a) for WPNSTA Yorktown.

Soil cuttings and drilling water generated during the drilling program (i.e., IDW) were returned to the site according to the procedures outlined in Section 2.8.

Site 21

Two soil borings (21BS/GW02 and 21BS/GW01A) were advanced at the site. One of the borings (21SB/GW01A) was advanced in the upgradient portion of the site and the second boring was advanced adjacent to 21GW02. Both of the borings were advanced to facilitate well installation. Boring 21SB/GW01A was advanced for the installation of a Type III monitoring well and Boring 21SB/GW02 was advanced for the installation of a Type II monitoring well. All soil borings, whether or not they were sampled for chemical analysis, were advanced using a split-spoon sampler and hollow-stem augers. Standard operating procedures (SOPs) for soil boring advancement and subsurface soil sampling are presented in the Final Master FSP (Baker, 1994a) and Section 4.1.1 of the site-specific work plan for the site.

Two subsurface soil samples were collected from 21SB/GW01A at depths of 36- to 38-ft and 50- to 52-ft. The samples were analyzed for TOC, CEC, pH, bulk density, and grain size to evaluate the fate and transport of contaminants within the subsurface (Table 2-3).

Each split-spoon was classified visually by the on-site geologist. Lithological descriptions of the soil are provided on the Test Boring Records and Well Construction Records in Appendix A. Specific sampling and soil classification procedures are outlined in Sections 4.1.1 and 4.2.1 of the Final Work Plan for Sites 4, 21, and 22 (Baker, 1996) and Section 3.9 of the Final Master FSP (Baker, 1994a) for WPNSTA Yorktown.

Soil cuttings and drilling water generated during the drilling program (i.e., IDW) were returned to the site according to the procedures outlined in Section 2.8.

Site 22

Twenty-one subsurface (deeper than 6-inches bgs) soil samples were collected from six soil borings (22SB/GW01, 22SB/GW01A, 22SB/GW02, 22SB/GW03, 22SB/GW04, and 22SB/GW05) to evaluate the horizontal and vertical extent of potentially impacted soil and for the RA evaluation purposes. The soil borings are located around the periphery of the circular site as presented on Figure 2-4. The borings were advanced to depths of 24- to 47-ft bgs. Descriptions of the lithology from split-spoon samples indicate that groundwater was encountered at 16- to 17-ft bgs.

From five of the six borings, two subsurface soil environmental samples were collected; one from the approximate mid-point of the boring (7- to 9-ft bgs), and one from just above the top of the water table (15- to 17-ft bgs). Environmental subsurface soil samples were not collected from 22SB/GW01A because the soil boring was used to install the second well of a cluster (22GW01 and 22GW01A). In addition to environmental sampling, three samples were collected to access the fate and transport of contaminants. One of the samples were collected just above the groundwater table and two were collected below the groundwater table (within the screened interval of deep and shallow monitoring wells 22GW01 and 22GW01A). The sampling protocols were described in Section 3.9 of the Final Master FSP (Baker, 1994a) and Sections 4.1.1 and 4.2.1 of the Final Work Plan for Sites 4, 21, and 22 (Baker, 1996).

The environmental subsurface soil samples were analyzed for TCL volatile organics, TCL semivolatile organics, nitramine compounds, pesticides/PCBs, TAL inorganics, TOC, and nitrate/nitrite. The samples collected to access the fate and transport of contaminants were analyzed for CEC, grain size, and bulk density. Table 2-3 summarizes the analytical program for subsurface soil investigation.

All six of the soil borings were advanced at the site to install monitoring wells for groundwater sampling. Two of the soil borings (22BS/GW01 and 22BS/GW01A) were advanced for the installation of a shallow (25-ft bgs) well and a deeper (47-ft bgs) monitoring well and remaining four borings (22BS/GW02, 22BS/GW03, 22SB/GW04 and 22SB/GW05) were advanced for the installation of shallow (25-ft bgs) monitoring wells. All soil borings, whether or not they were sampled for chemical analysis, were advanced using a split-spoon sampler and hollow-stem augers. Standard operating procedures (SOPs) for soil boring advancement and subsurface soil sampling are

presented in the Final Master FSP (Baker, 1994a) and Section 4.1.1 of the site specific work plan for the site.

Each split-spoon was classified visually by the on-site geologist. Lithological descriptions of the soil are provided on the Test Boring Records and Well Construction Records in Appendix A. Specific sampling and soil classification procedures are outlined in Sections 4.1.1 and 4.2.1 of the Final Work Plan for Sites 4, 21, and 22 (Baker, 1996) and Section 3.9 of the Final Master FSP (Baker, 1994a) for WPNSTA Yorktown.

Soil cuttings and drilling water generated during the drilling program (i.e., IDW) were returned to the site according to the procedures outlined in Section 2.8.

2.2.2 Groundwater Investigation

The Round Two RI groundwater sampling program developed for Sites 4, 21, and 22 was designed to determine if former site activities adversely impacted the quality of groundwater. Moreover, the program was developed to consider potential human health and ecological risks associated with the Contaminants of Potential Concern (COPCs).

In general, the field procedures and sampling methods employed for the groundwater investigation were implemented in accordance with USEPA Region III SOPs. These procedures also included sample handling and preservation, documentation, and chain-of-custody procedures. Specific sampling procedures are outlined in Section 4.2.2 of the Final Work Plan for Sites 4, 21, and 22 (Baker, 1996) and Sections 3.14 and 3.15 of the Final Master FSP (Baker, 1994a) for WPNSTA Yorktown.

2.2.2.1 Monitoring Well Installation

As mentioned in Section 2.2.1.2, two types of monitoring wells were installed during this field program, Type II (no surface casing) and Type III (surface casing) monitoring wells. The following subsections describe the type and locations of monitoring wells installed during the field program and Table 2-4 presents a summary of well construction details for all the wells at the sites. Refer to Section 3.3 for a discussion of aquifers.

2.2.2.1.1 Site 4 Monitoring Wells

Four Type II monitoring wells (4GW06, 4GW06A, 4GW02A, and 4GW05A,) and one Type III (4GW01A) monitoring well were installed at Site 4. The Type III (surface cased) monitoring well (4GW01A) was installed at an upgradient location (adjacent to 4GW01) where a significant shallow groundwater unit (the equivalent of the Columbia aquifer) was encountered. This shallow groundwater unit was encountered at a depth of 10-ft bgs which is at an elevation higher than the groundwater beneath the site (Yorktown-Eastover aquifer) that was encountered at a depth of 18- to 28-ft bgs. The 10-inch steel casing of this monitoring well (4GW01A) was installed 2.5-ft into the Cornwallis Cave confining unit at a depth of 21.5-ft. bgs to insure a proper seal between strata. This seal will mitigate the potential downward migration of perched groundwater along the borehole/well interface. The surface casing was grouted in place and allowed to set overnight. The borehole was then advanced through the 10-inch casing and the well was completed within the upper portions of the underlying Yorktown-Eastover aquifer at a depth of 50.5-ft bgs. Subsequent monitoring well installation and construction procedures were the same as those employed for the shallow monitoring wells except that a bentonite slurry was placed above the sand pack in place of the bentonite pellets. The top of the sand pack remained at least two feet below the bottom of the confining unit. Typical Type III monitoring well construction details are shown in Appendix A for above ground completion.

The remaining Type II monitoring wells were completed within the upper and lower portions of the Yorktown-Eastover aquifer and achieved depths of 31- to 80.5-ft bgs. The shallow monitoring well (4GW06) was installed at similar depths as the existing wells (4GW02, 4GW03, 4GW04, and 4GW05). The deeper monitoring wells (4GW06A, 4GW02A, and 4GW05A) were installed at depths where the subsurface soil became more dense and the moisture changed from wet to moist/wet. Due to the greater density and lower moisture of the soil the vertical component of the groundwater flow would be minimal. Therefore, contaminants with a specific gravity greater than water would migrate horizontally more easily than vertically. The surficial groundwater was encountered at depths ranging from 25- to 32-feet bgs and the total depth of the monitoring wells ranged from 45- to 81-feet bgs. In addition, the depths of the wells were designed to monitor the upper and lower aquifer zones. Typical shallow monitoring well construction details are shown in Appendix A for above ground completion. Refer to cross-sections A-A' through E-E' in Section 3.0

for a graphical depiction of monitoring well depth and vertical position within the aquifers at Sites 4, 21, and 22.

Well construction details for the existing and newly installed monitoring wells are summarized in Table 2-4 and are shown on the Well Construction Records provided in Appendix A. Specific monitoring well installation procedures are outlined in Sections 4.1.2 and 4.2.2 of the Final Work Plan for Sites 4, 21, and 22 (Baker, 1996) and Sections 3.10 and 3.11 of the Final Master FSP (Baker, 1994a) for WPNSTA Yorktown.

Site 21

A Type II monitoring well (21GW02) and a Type III (surface cased) monitoring well (21GW01A) were installed at Site 21 (Figure 2-4). The Type III monitoring well (21GW01A) was installed at an upgradient location (adjacent to 21GW01) where a significant shallow groundwater unit (the equivalent of the Columbia Aquifer) was encountered. This shallow groundwater unit was encountered at a depth of 10-ft bgs at an elevation higher than the groundwater beneath the site (Yorktown-Eastover aquifer) that was encountered at a depth of 18- to 28-ft bgs. The 10-inch steel casing of this monitoring well (21GW01A) was installed 2.5-ft into the Cornwallis Cave Confining unit at a depth of 24-ft. bgs to insure a proper seal between strata. This seal will mitigate the potential downward migration of perched groundwater along the borehole/well interface. The surface casing was grouted in place and allowed to set overnight. The borehole was then advanced through the 10-inch casing and the well was completed within the upper portions of the underlying Yorktown-Eastover aquifer at a depth of 55-ft bgs. Subsequent monitoring well installation and construction procedures were the same as those employed for the shallow monitoring wells except that a bentonite slurry was placed above the sand pack in place of the bentonite pellets. The top of the sand pack remained at least two feet below the bottom of the confining unit. Typical Type III monitoring well construction details are shown on Appendix A for above ground completion.

The Type II monitoring well was installed to replace 21GW02 which was damaged during the removal action. This well was completed within the upper portion of the Yorktown-Eastover aquifer at the same depth as the former monitoring well 21GW02 (Weston well). The surficial groundwater was encountered at a depth of 32-feet bgs and the total depth of the monitoring well is 47-feet bgs.

Refer to cross-sections A-A' through E-E' in Section 3.0 for a graphical depiction of monitoring well depth and vertical position within the aquifers at Sites 4, 21, and 22.

Well construction details for the existing and newly installed wells are summarized in Table 2-4 and are shown on the Well Construction Records provided in Appendix A. Typical shallow monitoring well construction details are shown on Appendix A for above ground completion. Specific monitoring well installation procedures are outlined in Sections 4.1.2 and 4.2.2 of the Final Work Plan for Sites 4, 21, and 22 (Baker, 1996) and Sections 3.10 and 3.11 of the Final Master FSP (Baker, 1994a) for WPNSTA Yorktown.

Site 22 Monitoring Wells

Six Type II monitoring wells (22GW01, 22GW01A, 22GW02, 22GW03, 22GW04, and 22GW05) were installed as shown on Figure 2-4 at Site 22. The monitoring wells were completed within the upper and lower portions of the Yorktown-Eastover aquifer and achieved depths of 24 to 47 ft bgs. The shallow monitoring wells (22GW01, 22GW02, 22GW03, 22GW04, and 22GW05) were installed within the upper 10- to 15-ft of the aquifer. The deeper monitoring well (22GW01A) was installed at depths where the subsurface soil became more dense and the moisture changed from wet to moist/wet. Due to the greater density and lower moisture of the soil the vertical component of groundwater flow would be minimal. Therefore, contaminants with a specific gravity greater than water would migrate horizontally more easily than vertically. The surficial groundwater was encountered at a depth of 16-ft. bgs and the total depth of the monitoring wells ranged from 26- to 47-feet bgs. Typical shallow monitoring well construction details are shown in Appendix A for above ground completion. Refer to cross-sections A-A' through E-E' in Section 3.0 for a graphical depiction of monitoring well depth and vertical position within the aquifers at Sites 4, 21, and 22.

Well construction details for the newly installed shallow wells are summarized in Table 2-4 and are shown on the Well Construction Records provided in Appendix A. Specific monitoring well installation procedures are outlined in Sections 4.1.2 and 4.2.2 of the Final Work Plan for Sites 4, 21, and 22 (Baker, 1996) and Sections 3.10 and 3.11 of the Final Master FSP (Baker, 1994a) for WPNSTA Yorktown.

2.2.2.2 Well Development

All of the existing monitoring wells were redeveloped at the beginning of the field program. Following well construction and curing of the bentonite and grout seals (i.e., 48 hours or more), each newly installed well was developed to remove fine-grained sediment from the screen and to establish interconnection between the well and the formation. The monitoring wells were developed by a combination of surging and pumping (with an above-ground Waterra pump). All equipment (i.e., polyethylene tubing) inserted down the monitoring wells was dedicated to that specific monitoring well and discarded following use. Specific well development procedures are outlined in Section 3.12 of the Final Master FSP (Baker, 1994a) and in Section 4.1.2.2 of the Final Work Plan for Sites 4, 21, and 22 (Baker, 1996).

Measurements of pH, specific conductance, and temperature were recorded to assist in determining well stabilization. Well Development Forms summarizing this information are provided in Appendix B.

2.2.2.3 Groundwater Sampling

The following subsections describe the groundwater sampling procedures and the analytical requirements for the groundwater samples collected. The samples were collected to confirm the presence or absence of contaminants and evaluate overall groundwater chemistry. Groundwater samples were collected from five new monitoring wells (4GW01A, 4GW02A, 4GW05A, 4GW06, and 4GW06A) and three existing monitoring wells (4GW02, 4GW03, and 4GW04) at Site 4, two new monitoring wells (21GW01A and 21GW02) and two existing monitoring wells (21GW03 and 21GW04) at Site 21, and six new monitoring wells (22GW01, 22GW01A through 22GW05) at Site 22. Figure 2-4 shows the well locations. Monitoring wells 4GW01 and 21GW01 were not sampled because they are set within the Columbia aquifer which is situated above the Yorktown-Eastover aquifer (which is the aquifer identified at all three sites) separated by a confining unit. In addition, groundwater samples collected during the Round One RI did not indicate the presence of organic contaminants in the deep aquifer. Groundwater sampling procedures, discussed below, were performed in accordance with USEPA Region III SOPs.

2.2.2.3.1 Procedures

Prior to groundwater purging, water levels from each well were measured and well volumes were calculated according to Section 4.1.2.3 of the Final Master FSP (Baker, 1994a) for WPNSTA Yorktown. Following well volume calculations, a minimum of three to five well volumes were purged from each well prior to sampling. Measurements of pH, specific conductance, temperature, and nephelometric turbidity units (NTUs) were recorded to determine groundwater stabilization and are presented on Table 2-5. Water was purged from each well using a low flow pump (peristaltic) and disposable polyethylene bailer. Low flow pumping was utilized when the static water level within the monitoring well was less than 25-feet bgs. When the static water level was greater than 25-feet bgs purging was completed by using both bailers and the Waterra pump. Purge water was returned back to the site as described in Section 2.5. Section 4.1.2.3 of the Final Work Plan for Sites 4, 21, and 22 (Baker, 1996) outlines the protocol for purging wells.

Groundwater samples were collected using either disposable polyethylene bailers dedicated to each monitoring well or a low flow pump (peristaltic) with dedicated tubing. The samples were introduced into laboratory-prepared and certified, preserved sample containers and stored on ice. Sample bottles for the VOC analysis were filled first, followed by SVOCs (including pesticides/PCBs and nitramines), TAL inorganics, and finally the engineering/water quality parameters. Samples analyzed for dissolved inorganics were filtered in the field (via peristaltic pump) or were collected in laboratory-prepared and certified bottles and filtered prior to placement in preserved bottles for shipment to the laboratory. The samples were filtered through a disposable 0.45 micron membrane.

Preparation of groundwater samples incorporated procedures similar to those described for the other samples. Sample collection information, including well number, sample identification number, time, date, samplers, and analytical parameters, was recorded in the field logbook and on the sample labels. Chain-of-custody documentation accompanied the samples to the laboratory. Specific sampling procedures are outlined in Section 4.1.2.3 in the Final Work Plan for Sites 4, 21, and 22 (Baker, 1996) and Section 3.15 of the Final Master FSP (Baker, 1994a) for WPNSTA Yorktown. The analytical program for the groundwater investigation is summarized in Table 2-6.

2.2.2.4 Water Level Measurements and Surveying

Static water level measurements were collected twice during the field investigation from top-of-casing (TOC) reference points at each newly installed well and existing wells after they were developed. Water level data was used to evaluate groundwater flow patterns (i.e., horizontal hydraulic gradient) and help estimate the groundwater/surface water interaction at the site. Measurements were recorded using an electric measuring tape to the nearest 0.01-foot. The water level measurements were collected on November 11 and 19, 1996 and are presented in Table 2-7 (converted to elevations msl).

After drilling was completed, all on-site monitoring wells and staff gauges were surveyed to establish vertical elevation in relation to mean sea level (msl) and horizontal control. Vertical accuracy of each well (established to TOC at each well) was measured to 0.01 foot and horizontal accuracy to within 0.01 foot. Control was established by using horizontal and vertical control points near the site that are tied into the Virginia State Plan Coordinate System. A registered surveyor in Virginia (Patton, Harris, Rust, and Associates, P.E.) was retained to perform the survey. Specific procedures are outlined in Section 4.4.1 of the Final Work Plan for Sites 4, 21, and 22 (Baker, 1996) and Sections 3.17 and 3.21 of the Final Master FSP (Baker, 1994a) for WPNSTA Yorktown.

2.2.2.5 In-Situ Hydraulic Conductivity Testing Procedures

In situ hydraulic conductivity tests ("slug tests") were performed in two monitoring wells (4GW02A and 4GW06) at Site 4, one monitoring well (21GW01A) at Site 21, and two monitoring wells (22GW01 and 22GW01A) at Site 22 after the groundwater sampling was completed, to determine aquifer hydraulic conductivity in the vicinity of the well. The tests were performed using solid PVC slugs and clean bailer rope. A pressure transducer attached to an electronic recording device (Hermit™ data logger) was used to record the test data. Two Type II monitoring wells, 4GW06 and 22GW01, were selected to reflect unconfined conditions, and three Type III monitoring wells, 4GW02A, 21GW01A, and 22GW001A, were selected to reflect confined conditions, within the three sites. The results of the slug tests are discussed in greater detail in Section 3.3.2 and presented in Appendix C. Specific testing procedures are outlined in Section 3.16 of the Final Master FSP (Baker, 1994a) for WPNSTA Yorktown.

2.2.3 Surface Water, Sediment, and Biota Investigation

Surface water and sediment samples were collected in August 1996 to ensure that the surface water conditions are consistent with when the background samples (WPNSTA Background Report, Baker, 1995) were collected. A summary of the Site 4 surface water sampling program describing the sample designations, collection dates, and analytical parameters is provided in Table 2-8. A summary of the Site 4 and 22 sediment sampling program is provided in Table 2-9. Surface water and sediment locations are presented on Figure 2-5. The locations were chosen to coincide with the aquatic ecological sampling stations.

2.2.3.1 Surface Water

The data from the surface water investigation conducted at Site 4, 21, and 22 within the east branch of Felgates Creek was used to assess potential impacts to the environment from the sites. It was also used in conjunction with the biota data in the ecological RA. The surface water/sediment samples reference Site 4 (i.e., 4SW/SD07) but are representative of the surface water that drains all three sites.

Six surface water and sediment sampling stations were identified to characterize the east branch of Felgates Creek (including the unnamed tributary located between Sites 4 and 21) (Figure 2-5). These sample locations were chosen to coincide with the aquatic ecological sampling locations. One surface water sample was collected from midstream at each sampling location.

Samples were collected to represent surface water ambient conditions. Surface water was collected directly into a laboratory-supplied and certified sample bottle. The sample bottle was placed with the open end downstream to minimize collecting particulate matter or sediments in the water sample. All sample containers not containing preservative were rinsed at least once with the surface water prior to final sample collection. Downstream water samples were collected first, with subsequent samples taken while moving upstream. Sediment samples were collected after the water samples to minimize sediment resuspension which might contaminate the water samples.

For those sample bottles that contained preservative (e.g., sulfuric acid, nitric acid, or sodium hydroxide), the water was collected in a clean, decontaminated sample bottle and then slowly transferred into the appropriate preservative-containing sample bottle.

The samples were filtered in the field through a disposable 0.45 micron membrane. A peristaltic pump was used for the filtering procedure. Sample preparation also included documentation of sample number, location, date, and time in a field logbook and on the sample labels. Chain-of-custody documentation accompanied the samples to the laboratory. Specific sampling procedures are outlined in Section 4.1.3 of the Final Work Plan for Sites 4, 21, and 22 (Baker, 1996) and Section 3.7.1 of the Final Master FSP (Baker, 1994a) for WPNSTA Yorktown.

Table 2-8 summarizes the environmental samples to be collected and analytical parameters for the surface water samples. In addition, analyses for temperature, dissolved oxygen, salinity, specific conductivity, and turbidity were performed (Appendix K, field data forms) on surface water samples in the field. The procedures for performing these measurements can be found in the Master FSP, Section 3.29 (Baker, 1994a).

2.2.3.2 Sediment

Sediment sampling was conducted at all six of the surface water/sediment sampling stations and at four additional sediment locations: three at the southern portion of Site 22 and one at a small tributary to Felgates Creek west of Site 22. A summary of the sediment sampling program, outlining the sample identification, collection date, sample interval, and analytical methods is provided in Table 2-9.

Surface (0- to 4-inches) and subsurface (4- to 8-inches) sediment samples were collected for chemical analysis with a sediment sleeve. The coring sleeve was pushed into the sediment to a depth of 12 inches or until refusal. The sediment samples were extruded with a decontaminated extruder into a laboratory-supplied and certified sampling bottle.

Sediment samples were prepared according to USEPA Region III SOPs. Following sample collection, each sample was stored on ice in a cooler. Sample preparation also included documentation of sample number, location, date, and time in a field logbook and on the sample labels. COC documentation accompanied the samples to the laboratory. Specific sampling procedures are outlined in Section 4.1.3 of the Final Work Plan for Sites 4, 21, and 22 (Baker, 1996) and in Section 3.7 of the Final Master FSP (Baker 1994a) for WPNSTA Yorktown.

2.2.3.3 Biota Investigation

Aquatic ecological investigations were conducted at the six surface water/sediment locations shown in Figure 2-5. In general, the field procedures and sampling methods employed for the biota investigation were implemented in accordance with USEPA Region III SOPs. These procedures also included sample handling and preservation and documentation procedures. Specific sampling procedures are outlined in Section 4.1.4 of the Final Work Plan for Sites 4, 21, and 22 (Baker, 1996) and Section 3.18 of the Final Master FSP (Baker, 1994a) for WPNSTA Yorktown.

Biota samples were collected from the east branch of Felgates Creek during the Round Two RI. Fish were collected with hoop nets, gill nets, dip nets, and cast nets. Benthic macroinvertebrate samples were collected with the Ponar grab sampler. Specific details on biota sampling at Sites 4, 21, and 22 are provided in Section 7.4.

2.2.4 Dioxin Investigation - Sites 4, 21, 22, and Background

In July 2000 thirteen surface soil samples (0- to 6-inches bgs) were collected throughout Naval Weapon Station Yorktown and analyzed for dioxins and dibenzofurans. Sites 4, 21, and 22 were identified as candidate sites for dioxin analysis because of the historic burning of explosives and waste materials that may have contained residual chlorinated solvents such as TCE.

Eight of the samples were collected at Sites 4, 21, and 22. Two of the samples were collected from Site 4 in the downgradient vicinity of the former ash pile. Two of the samples were collected from Site 21 in a depositional area downgradient of the Site 4 former ash pile, and four samples were collected at Site 22 around the burn pad in areas downgradient of the predominant wind direction and in depositional areas. Figures 4-22, 4-23, and 4-24 present the sample locations. In addition,

five surface soil samples were collected at background locations. Four of the sample areas were located at previous background surface soil locations (BS05, BS10, BS19, and BS31) and one location (BS41) was sampled at a new background location. Figure 4-25 presents the background sample locations.

The samples were collected with dedicated stainless steel spoons and bowls to a depth of 6-inches bgs. Care was taken to obtain undisturbed soils from each site that could have been affected by past disposal practices. Results from the Round Two RI were used to establish locations that were approved during formal partnering activities between LANTDIV, USEPA, and Virginia Department of Environmental Quality (VDEQ) personnel.

2.3 Quality Assurance/Quality Control Sampling Procedures

Field QA/QC samples were collected during the sampling program. These samples were obtained to: (1) ensure that decontamination procedures were properly implemented (i.e., equipment rinsate blanks); (2) evaluate field methodology (i.e., duplicate samples); (3) establish field background conditions (i.e., field blanks); and (4) evaluate whether cross-contamination occurred during sampling and/or shipping (i.e., trip blanks).

Several types of field QA/QC samples were collected and analyzed including duplicate samples, equipment rinsate blanks, field blanks, and trip blanks. A complete discussion of the QA/QC procedures can be found in Section 8.0 of the Master Quality Assurance Project Plan (QAPP) (Baker, 1994c). The QA/QC Sampling Program for soil is outlined in Table 2-10; for groundwater in Table 2-11; for surface water on Table 2-12; for sediment in Table 2-13; and for all media in Table 2-14.

2.4 Decontamination Procedures

Decontamination procedures for heavy equipment (i.e., drilling augers), personnel, and sampling equipment were followed as per Section 3.25 of the Final FSP (Baker 1994a) for WPNSTA Yorktown. For sampling equipment, the decontamination procedures includes a soap and water wash with liquinox; rinse with deionized water; rinse with nitric acid; rinse with deionized water; and a final rinse with methanol before air drying. Heavy equipment decontamination included steam

cleaning on a decontamination pad. Decontamination fluids were handled as outlined in Section 2.5 of this report.

2.5 Investigation Derived Waste Management

Wastes generated during the field investigation include soil from subsurface borings (cuttings), groundwater (from developing and purging wells), decontamination fluids, (steam cleaning water and decontamination chemicals) and miscellaneous items such as gloves, Tyvek®, and other used personal protective equipment (PPE). The soil cuttings (from borings and well installation), groundwater (purge and development water), and steam cleaning decontamination water were returned to the site. The decontamination chemicals and miscellaneous items were properly contained until disposal. IDW management (soil and groundwater) was conducted in accordance with guidance from USEPA's Guide to Management of Investigation-Derived Wastes (USEPA, 1992). The document states that "most IDW (with the exception on non-indigenous IDW) generated during the course of the investigation are intrinsic elements of the site and should be managed with other wastes from the site, consistent with final remedy." The analytical results from the Round One RI for Sites 4 and 21 indicate that soil and groundwater generated during field investigative activities would not be classified as hazardous waste. In addition, Round Two Remedial investigations have been performed at eight sites at WPNSTA Yorktown. All of the composite samples collected from roll-off boxes (soil) and tankers (development, purge and steam cleaning decontamination water) have been determined as non-hazardous.

The IDW management procedures are described below.

Soil

Soil generated (soil cuttings and split-spoon samples) during field investigative activities was spread on the ground in the immediate vicinity of the boring activities.

Liquid

Liquid generated during field activities included development and purge water from monitoring wells (groundwater), decontamination from steam cleaning activities, and decontamination fluids containing solvents and acids. These were segregated and stored as noted below.

Development, purge, and decontamination (generated by steam cleaning only) water from the site was discharged on the ground.

Personal Protective Equipment

Items of PPE that may have come into contact with potentially contaminated materials, such as disposable gloves, Tyvek®, and disposable bailers, were decontaminated as appropriate and double bagged in plastic bags, and placed in the trash dumpster at Baker's Field Trailer.

2.6 References

American Society for Testing and Materials (ASTM). 1983. Standard Practice for Thin-Walled Tube Sampling of Soils. ASTM Method D1587-83 (04.98), Annual Book of ASTM Standards, Philadelphia, Pennsylvania.

American Society for Testing and Materials (ASTM). 1984. Standard Method for Penetration Test and Split-Barrel Sampling of Soils. ASTM Method D1586-84, Annual Book of ASTM Standards, Philadelphia, Pennsylvania.

Baker Environmental, Inc. 1994a. Final Master Field Sampling Plan, Naval Weapons Station, Yorktown, Yorktown, Virginia. June 1994.

Baker Environmental, Inc. 1994b. Final Master Health and Safety Plan, Naval Weapons Station Yorktown, Yorktown, Virginia. June 1994.

Baker Environmental, Inc. 1994c. Final Master Quality Assurance Project Plans, Naval Weapons Station Yorktown, Yorktown, Virginia. June 1994.

Baker Environmental, Inc. 1996. Final Work Plan for Sites 4, 21, and 22, Naval Weapons Station Yorktown, Yorktown, Virginia. March 1996.

Baker Environmental, Inc. 1995. Summary of Background Constituent Concentrations and Characterization of the Biotic Community from the York River Drainage Basin, Naval Weapons Station Yorktown, Yorktown, Virginia. March 1995.

United States Environmental Protection Agency. 1990. Macroinvertebrate Field and Laboratory Methods for Evaluating the Biological Integrity of Surface Waters. Office of Research and Development, Washington, D.C. EPA/600/4-90/030. November 1990.

4.0 NATURE AND EXTENT OF CONTAMINATION

This section presents chemical analytical results obtained as part of the Round Two RI performed at Sites 4, 21, and 22 and discusses the Round One, the Post-Removal Confirmation, and Round Two sampling results. The objectives of this section are to characterize the nature and delineate the extent of possible site contamination. The characterization of Sites 4, 21, and 22 is based upon collection and analysis of samples of the following environmental media: surface and subsurface soil, groundwater, surface water, sediment, and biota.

The analytical results are presented in two groups. Non-site related analytical results, presented in Section 4.1, include laboratory contaminants, essential nutrients, and naturally occurring inorganic elements. Analytical results from the environmental investigation presented in Section 4.2, include results of the soil, groundwater, surface water, and sediment investigations (Section 7.0 presents the results of the biota sampling). Section 4.2 includes the environmental sample results (i.e., soil samples collected from within the study area) and related background sample results (i.e., Station-wide background soil samples) to evaluate whether or not the detected constituents (particularly the inorganics) are site-related. Section 4.3 describes the extent to which contaminants have migrated from probable source areas and the potential for future migration using the Round One, Post-Removal Confirmation, and Round Two sampling results.

Appendices D through G present the Round Two chain-of-custody forms, Round Two sampling summary, Round Two analytical laboratory results, and Round Two QA/QC results, respectively. Figures 4-1 through 4-21 provide a graphical depiction of select organic and inorganic contaminants as they occur throughout the site. Positive detections of organic compounds and inorganic analytes according to media are presented in summary tables included at the end of this section (Tables 4-4 through 4-41).

4.1 Potential Non-Site Related Analytical Results

Potentially, many of the organic compounds and inorganic constituents detected during the investigations of the various environmental media could be attributed to non-site related conditions. Contaminants found in either field or laboratory blanks and the presence of naturally occurring constituents may both interfere with evaluation of actual site-related contaminants.

4.1.1 Sampling/Laboratory Contaminants

Blank samples provide a measure of contamination that has been introduced into a sample set during its collection, transportation, preparation, and/or analysis. Common contaminants of this type include acetone, methylene chloride, chloroform, and the phthalates. The concentrations of chemicals detected in blanks were compared with concentrations of the same chemicals detected in environmental samples by the independent validator. The validator qualified the environmental samples with a "B" according to the specific QA/QC sample. Table 4-1 presents the environmental samples and their associated QA/QC samples.

Other qualifiers are also added to sample results during data validation. The "J" qualifier indicates that the reported sample concentration has been estimated. J-qualified data has been used in the discussion of nature and extent of contamination. A list of the qualifiers and their definitions is presented in Table 4-2.

4.1.2 Naturally Occurring Inorganic Elements

Unlike organics, many of the inorganic parameters for which environmental samples were analyzed do occur naturally. For example, lead is an element that occurs naturally in most soil (in low concentrations), but also is considered a contaminant if its concentration is well above background levels and its presence can be attributed to site operations (e.g., lead from lead-based paints or batteries).

In order to differentiate between inorganic contamination from site operations and naturally-occurring inorganic elements, the results of the sample analyses (concentrations) were compared to information regarding background conditions at WPNSTA Yorktown. This information was collected during a Station-wide investigation in 1994 and presented in the Summary of Background Constituent Concentrations and Characterization of the Biotic Community from the York River Drainage Basin (Baker, 1995). A summary of these data is provided in Table 4-3.

4.1.3 Pesticides

Pesticides commonly occur throughout Tidewater Virginia because of past pest-control activities like aerial spraying of DDT to control mosquitos. While pesticides will be evaluated in the human health and ecological risk assessments, they have not been included on the figures presenting nature and extent of contamination. This will allow a focus on site-related organic compounds and how they occur on site. Pesticide information is included in the summary tables at the end of this section.

4.2 Nature of Contamination

The following subsections present analytical results for the environmental samples collected during the removal action at Sites 4 and 21 and the Round Two RI at Sites 4, 21, and 22. Analytical results are presented for the following:

- Surface and subsurface soil investigation
- Groundwater investigation
- Surface water investigation
- Sediment investigation

In addition, a biota investigation was conducted. Results of this investigation, which included fish and benthic macroinvertebrate sampling, are discussed in the ecological risk assessment.

Tables 4-4 through 4-41 present all the organic and inorganic contaminants detected in the samples. In order to limit the number of detections depicted on the figures and to better show hot spots only, selected detections are shown on Figures 4-1 through 4-21. All organic compounds and inorganic analytes will be evaluated in the risk assessment.

Laboratory contaminants and naturally occurring constituents detected in the various samples are not evaluated in this section. Inorganic constituents considered to be essential human nutrients will not be addressed in this section. Essential nutrients include calcium, magnesium, potassium, and sodium (USEPA, 1989).

Results of the biota investigation are presented in Section 7.0 (Ecological Risk Assessment).

4.2.1 Site 4 Analytical Results

The following sections present analytical results for the environmental samples collected during the Post-Removal Action confirmatory sampling (IT Corp., 1994) and Round Two RI at Site 4. As noted in Section 2.3, the surface soil samples collected (4SS01 through 4SS42) during the Post-Removal confirmatory sampling (IT Corp., 1994) were analyzed for VOCs, SVOCs, pesticides, PCBs, and inorganics. The surface soil samples collected (4SS43 through 4SS50) during the Round Two (Baker) RI investigation were analyzed for the same parameters except VOCs.

Site 4 has been divided into two separate areas for this discussion, Site 4 Proper and Site 4 Hot Spot.

4.2.1.1 Soil Investigation

The analytical results from the surface and subsurface soil investigation are discussed in the following sections.

Surface Soil Investigation Results-Site 4 Proper

Results of the Round One investigation indicated that soil at Site 4 was contaminated with SVOCs, PCBs, and explosives. Most of the SVOCs were PAHs. Copper, lead, and zinc, possibly from battery disposal, were also identified. Analysis of the data indicated that additional investigations were warranted.

The results of the Round One RI and the Post-Removal Action confirmatory sampling were used to select sampling locations for the Round Two RI. In general, the results of the Round Two surface soil investigation at Site 4 were consistent with the Round One results. Site 4-Proper consists of 51 surface soil samples collected throughout the site excluding samples 4SS34, 4SS35, 4SS36, and 4SS40 (which were designated Site 4 - Hot Spot). Figure 4-1 outlines the Site 4-Hot Spot within Site 4 (Proper).

Concentrations of the SVOCs (mainly Polynuclear Aromatic Hydrocarbons [PAHs]) were detected within twenty-nine of the fifty-one surface soil samples collected at Site 4-Proper. The majority of these detections of both carcinogenic and non-carcinogenic PAHs were at low levels. Concentrations

of benzo(a)anthracene, benzo(b)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, and dibenzo(a,h)pyrene exceeded the residential COC criteria.

Nitramine compounds were detected in six of the fifty-one surface soil samples. The compounds detected were 1,3-dinitrobenzene, 2,4,6-dinitrotoluene, 1,3,5-trinitrobenzene, HMX, RDX, and total amino-DNTs. Two of the samples had concentrations exceeding the residential COC criteria for at least one of the detected compounds. The majority of the nitramine detections are located in the northeast portion of the site, downgradient of an ash pile that has been removed.

Nineteen of 20 inorganics were detected in surface soil samples. Silver was not detected in the sample set.

Positive detections of organic compounds and inorganic analytes are presented, by sampling location, on Figures 4-2 and 4-3. Tables 4-4 through 4-6 summarize analytical results and engineering parameters for surface soils at Site 4-Proposed.

Surface Soil Investigation Results-Site 4 Hot Spot

The surface soil Hot Spot is comprised of the sample locations: 4SS34, 4SS35, 4SS36 and 4SS40; which are shown on Figure 4-1.

Concentrations of the SVOCs (mainly PAHs) were detected within the five surface soil samples collected at Site 4-AOC. Concentrations of carbazole, benzo(a)anthracene, benzo(b)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, and dibenzo(a,h)pyrene exceeded the residential COC criteria.

Nitramine compounds were not detected in any of the AOC surface soil samples.

Figure 4-2 presents the organic compounds detected at sample locations 4SS34, 4SS35, 4SS36 and 4SS40, and all positive detections (organics and inorganics) are presented on Table 4-7 and Table 4-8.

Thirteen of 20 inorganics were detected in hot spot surface soil samples. Beryllium, cadmium, cobalt, mercury, nickel, selenium, silver, thallium, and cyanide were not detected in the sample set. Arsenic, lead, and zinc were detected at levels exceeding Station-wide background concentrations in at least one of the samples.

Subsurface Soil Investigation Results

Subsurface soil samples were not collected during the Round One RI or during the Post Removal Action confirmatory sampling.

Subsurface soil samples were collected at the soil boring (4SB07 and 4SB08) and one of the new monitoring well locations (4SB06A) during the Round Two RI. Refer to Table 2-3 for a list of the samples collected and analysis performed.

Low estimated concentrations (4J $\mu\text{g/kg}$) of toluene were detected in two samples collected from one soil boring at Site 4.

Fourteen of 20 inorganics were detected within the subsurface soil samples. Antimony, cadmium, mercury, selenium, silver, and thallium were not detected in the sample set.

The organic compounds and the inorganic analytes detected at each location are presented in Figures 4-4 and 4-5. Tables 4-9 through 4-11 summarize analytical results including engineering parameters for subsurface soils at Site 4.

4.2.1.2 Groundwater Investigation Results

The following subsections discuss the results of samples collected from the Cornwallis Cave/Yorktown-Eastover aquifer at Site 4. Table 2-6 presents the samples collected and analysis performed.

During the Round One investigation, TCE was detected in two wells at Site 4, 4GW04 and 4GW05. No SVOCs were identified. Inorganics were prevalent in Site 4 groundwater, although they were distributed throughout the site.

VOCs, and nitramines were detected in eight of the ten groundwater samples collected at Site 4 during the Round Two RI (see Figures 4-6 and 4-7 and Tables 4-12 to 4-11).

Three of the monitoring wells (4GW03, 4GW04, and 4GW05) had concentrations of 1,2-dichloroethene and trichloroethene. The highest concentration of trichloroethene (9 µg/L) detected in 4GW04 and 4GW05 exceeded the Federal MCLs and the Commonwealth of Virginia PMCLs. These compounds were also detected (at the same well locations) during the Round One sampling event but at slightly lower concentrations. These monitoring wells are located between Sites 4 and 22 (Figure 4-6).

Four explosive compounds (2,4-DNT/2,6-DNT, 2,4,6-TNT, amino-DNTs, and RDX) were detected at relatively low levels within five groundwater samples from the monitoring wells: 4GW02, 4GW03, 4GW05, 4GW05A, and 4GW06. Positive detections are presented on Figure 4-6.

Relatively low concentrations of total inorganics were detected in the groundwater samples (Figure 4-7). Twelve of 19 inorganics were detected within the sample set. Nine of 20 dissolved inorganics were detected in the sample set. Antimony, beryllium, cadmium, copper, lead, mercury, selenium, silver, thallium, and zinc were not detected.

Positive detection summaries for the organic compounds, inorganic analytes, and engineering parameters are presented on Tables 4-12 through 4-14.

4.2.1.3 Surface Water and Sediment Investigation

The following subsections present a discussion on the analytical results for surface water and sediment samples collected within the east branch of Felgates Creek, the unnamed tributary to east branch of Felgates Creek between Sites 4 and 21, and within the marsh area adjacent to the main body of Felgates Creek west of Site 22. Tables 2-8 and 2-9 present the samples collected and the analysis performed. While the results for surface water and sediment are discussed as part of the Site 4 investigation, they pertain to Sites 21 and 22 as well.

Surface Water Investigation Results

Seven surface water samples were collected from the east branch of Felgates Creek, the unnamed tributary, and the marsh area adjacent to the main body of Felgates Creek. (See Figure 4-8 and Tables 4-15 to 4-17). There was no surface water at location 4SW/SD13 (marsh area west of Site 22); therefore, only a sediment sample could be collected.

Eight nitramine compounds (amino-DNT, 1,3-dinitrobenzene, 2,4-DNT/2,6-DNT, HMX, RDX, nitrobenzene, 1,3,5-trinitrobenzene, and 2,4,6-trinitrotoluene) were detected within the surface water samples. The majority of detections (4SW07 and 4SW08) were located within the upstream portion of the unnamed tributary that discharged into the east branch of Felgates Creek between Sites 4 and 21. These two samples (4SW07 and 4SW08) were located downstream of surface soil locations 4SS07, 4SS08, 4SS09, 4SS49, and 4SS50 (See Figure 4-2) where similar nitramine compounds were detected.

Twelve of 20 inorganics were detected within the sample set. Beryllium, mercury, nickel, selenium, silver, thallium, zinc, and cyanide were not detected within the sample set.

Positive detections for organic compounds, inorganic analytes, and engineering parameters are presented on Tables 4-15 through 4-17. Figures 4-8 and 4-9 present the organic compounds and select inorganic analytes detected within the samples.

Sediment Investigation Results

Fourteen sediment samples were collected from seven sampling locations within the east branch of Felgates Creek, the unnamed tributary, and the marsh area adjacent to the main body of Felgates Creek east of Site 22. (See Figure 4-10 and Tables 4-18 to 4-20). A shallow sample and a deep sample were collected from each location.

VOCs, SVOCs, and nitramines were detected in the sediment samples collected within the water bodies previously described. Two VOCs, benzene and tetrachloroethene, were detected at relatively low concentrations. The maximum detected concentrations were within samples 4SD09-01, 4SD10-01D, and 4SD11-02.

Seven SVOCs were detected in one sample (4SD07-02). The SVOCs were mainly PAHs and occurred at relatively low levels. None of the concentrations exceeded the sediment screening levels (effect range-low).

One nitramine compound, 2,4,6-TNT was detected in eight samples from four locations. The concentrations were all below the sediment screening levels.

Nineteen of 20 inorganics were detected in the sediment samples. Cyanide was not detected within the sample set.

Positive detections for organic compounds, inorganic analytes, and engineering parameters are presented on tables 4-18 through 4-20. Figures 4-10 and 4-11 present select organic compounds and select inorganic analytes detected within the samples.

Biota Investigation Results

The biota investigation for the Round Two investigation included benthic macroinvertebrate sampling and fish population sampling. These results are presented in Section 7.0 (Ecological Risk Assessment).

4.2.2 Site 21 Investigative Results

The following sections present analytical results for the environmental samples collected during the Round Two RI at Site 21 by media.

4.2.2.1 Soil Investigation

This section presents analytical results from the soil investigation (surface and subsurface soil) at Site 21. Surface soil results are depicted on Figures 4-12 and 4-13; subsurface soil results are depicted on Figures 4-14 and 4-15. Tables 4-21 through 4-23 summarize surface soil results for Site 21, Tables 4-24 through 4-26 summarize subsurface results.

Surface Soil Investigation Results

During the Round One RI VOCs, SVOCs, and inorganics, particularly copper, mercury, and zinc, were detected in surface soil at Site 21.

Twelve surface soil samples (21SS01 through 21SS05, 21SS09, 21SS11, 21SS12, and 21SS15 through 21SS18) were collected after the removal action performed by IT Corp. These samples were analyzed for VOCs, SVOCs, pesticide/PCBs, nitramine compounds, and TAL inorganics.

In addition, five surface soil samples (21SS19 through 21SS22, including one duplicate) were collected during the Round Two RI downgradient along the west and southwest portions of the site. These samples were analyzed for SVOCs, pesticide/PCBs, TAL inorganics, and engineering parameters.

SVOCs (mainly PAHs) were detected at relatively low concentrations within the sample set. Concentrations of benzo(b)fluoranthene and benzo(a)pyrene exceeded the residential COC criteria for residential soil in one sample (21SS15). There were no nitramine compounds detected.

Nineteen of 20 inorganics were detected in the surface soil samples. Antimony was not detected within the sample set.

Subsurface Soil Investigation Results

Subsurface soil samples were not collected during the Round One RI.

Six subsurface soil samples were collected at six locations at 0.5- to 1.5-ft bgs as part of the post removal action (shown on Figure 2-2) and analyzed for TCL VOCs and SVOCs, nitramine compounds, and TAL inorganics. In addition, one soil sample (21SB04-001) and a duplicate (21SB04-101) were collected from the soil boring due to the shallow depth of the groundwater. These two samples were analyzed for TCL organics and TAL inorganics.

These locations and select organic compounds and inorganic analytes detected at each location are presented in Figures 4-14 and 4-15. Tables 4-24 to 4-26 summarize all results for subsurface soil at Site 21.

Low concentrations of nine SVOCs were detected in the sample set. Nitramines were not detected in the subsurface soil samples.

Twelve of 20 inorganics were detected in the subsurface soil samples. Antimony, cadmium, cobalt, nickel, silver, thallium, and cyanide were not detected within the sample set.

4.2.2.2 Groundwater Investigation Results

Five groundwater samples (including one duplicate sample) were collected from three existing monitoring wells and one new monitoring well (21GW01A) at the site during the Round Two RI and analyzed for TCL organics, nitramine compounds, and TAL inorganics (total and dissolved). The existing monitoring well 21GW01 was not sampled because it is upgradient and not hydraulically connected to the site. (This well was constructed within the Columbia aquifer while the other wells are situated within the lower Yorktown-Eastover aquifer). Figures 4-6 and 4-16 present the organic compounds and select inorganic analytes detected within the groundwater samples and Tables 4-27 through 4-29 summarize the groundwater results for Site 21.

Low concentrations of the VOCs trichloroethene (21GW03) and 1,2-dichloroethene (21GW01A) were detected in the samples. These concentrations did not exceed the Federal MCLs or the Commonwealth of Virginia PMCLs.

Relatively low concentrations of fourteen total inorganics were detected in the groundwater samples. Antimony, beryllium, cadmium, mercury, silver, and thallium were not detected in the samples.

Relatively low concentrations of eleven dissolved inorganics were detected in the groundwater samples. Aluminum, antimony, beryllium, chromium, copper, lead, silver, and thallium were not detected within the sample set.

4.2.3 Site 22 Analytical Results

The following sections present analytical results for the environmental samples collected during the Round Two RI at Site 22 by media.

4.2.3.1 Soil Investigation

The analytical results from the surface and subsurface soil investigation are discussed below.

Surface Soil Investigation Results

Twenty-six surface soil samples (22SS01 through 22SS23, including three duplicates) were collected prior to the construction of the biocell at Site 22. The samples were analyzed for TCL organics (excluding VOCs), nitramine compounds, and TAL inorganics.

Low concentrations of the SVOCs (mainly PAHs) were detected within surface soil samples collected at Site 22.

Five nitramine compounds were detected in surface soil samples. The compounds detected were 2,4,6-dinitrotoluene, 1,3,5-trinitrobenzene, HMX, RDX, and total amino-DNTs. None of the compound concentrations exceeded the industrial or residential COC criteria. Figure 4-17 presents the organic compounds detected at the site and all positive detections are presented on Table 4-30.

Nineteen of 20 inorganics were detected in surface soil samples. Thallium was not detected in the sample set.

Positive detections of select organic compounds and inorganic analytes are presented, by sampling location, on Figures 4-17 and 4-18. Tables 4-30 through 4-32 summarize analytical results and engineering parameters for surface soils at Site 22.

Subsurface Soil Investigation Results

Fourteen subsurface soil samples were collected at the new monitoring well locations. Table 2-3 presents the samples collected and analysis performed. These locations, the organic compounds and the inorganic analytes detected at each location are presented in Figures 4-19 and 4-20. Tables 4-33 through 4-35 summarize analytical results including engineering parameters for subsurface soils at Site 22.

Low concentrations of toluene were detected in five samples. In addition, three nitramine compounds (2,4,6-trinitrotoluene, HMX, and RDX) were detected at concentrations below the residential COC criteria.

Seventeen of 20 inorganics were detected within the subsurface soil samples. Cadmium, silver, and cyanide were not detected in the sample set.

4.2.3.2 Groundwater Investigation Results

The following subsections discuss the results of samples collected from the Yorktown-Eastover aquifer at Site 22. Table 2-6 presents the samples collected and analyses performed. Figures 4-6 and 4-21 present detections of organic compounds and select inorganic analytes, and Tables 4-36 through 4-38 present all detections and engineering parameters.

VOCs, SVOCs, pesticides, and nitramine compounds were detected in the sample set (see Figure 4-6 and Tables 4-36 and 4-37).

Four of the monitoring wells (22GW01, 22GW01A, 22GW04, and 22GW05) had detectable VOC concentrations. Concentrations of 1,1-dichloroethene, 1,2-dichloroethene, 1,2-dichloroethane, 1,1,1-trichloroethane, and trichloroethene exceeded the Federal MCLs and the Commonwealth of Virginia PMCLs. The highest concentration of trichloroethene (1,200 µg/L) was detected in 22GW04 (Figure 4-6).

Low concentrations of three SVOCs were detected. The concentrations did not exceed the Federal MCLs or Virginia PMCLs.

Three explosive compounds (HMX, RDX, and tetryl) were detected within five groundwater samples from the monitoring wells 22GW01, 22GW01A, 22GW02, 22GW03 and 22GW04. Positive detections are presented on Figure 4-6.

Relatively low concentrations of total inorganics were detected in the groundwater samples. Ten of 19 inorganics were detected within the sample set.

Eleven of 19 dissolved inorganics were detected in the sample set. Antimony, cadmium, chromium, copper, lead, silver, thallium, and vanadium were not detected within the sample set.

4.2.3.3 Sediment Investigation

The following subsections present a discussion on the analytical results for sediment samples collected within the marsh area at the southern portion of Site 22 (See Figures 4-10 and 4-11 and Tables 4-39 to 4-41). There was no surface water within this area; therefore, surface water samples were not collected.

VOCs, SVOCs, pesticides, and nitramine compounds were detected in of the sediment samples.

Three SVOCs (fluoranthene, pyrene, and benzo(b)fluoranthene) were detected within the sample set at low levels.

One nitramine compound (2,4,6-TNT) was detected in one samples (22SD01-01) at low levels.

Seventeen of 20 inorganics were detected in the sediment samples. Mercury, vanadium, and cyanide were not detected within the sample set. Aluminum, antimony, arsenic, iron, manganese, and vanadium exceeded the residential COC criteria. All of the analytes had concentrations exceeding the maximum Station-wide background levels except for arsenic, barium, and manganese.

4.2.4 Dioxin Results

In July 2000 thirteen surface soil samples (0- to 6-inches bgs) were collected throughout Naval Weapon Station Yorktown and analyzed for dioxins and dibenzofurans. Eight of the samples were collected at Sites 4, 21, and 22 and five surface soil samples were collected at background locations.

The results of the dioxin sampling are presented on Table 4-42 and Figures 4-22, 4-23, 4-24, and 4-25. The results for Sites 4, 21, and 22 were similar to WPNSTA background results. The site results and background results were below the Agency for Toxic Substances and Disease Registry (ASTDR) environmental media evaluation guide (EMEG) value of 50 part-per-trillion (ppt). Results below the ASTDR EMEG value suggest that levels of dioxin detected at the sites will not cause adverse human health or environmental effects subsequent to exposure.

4.3 Extent of Contamination

This section describes the extent to which contamination has migrated at Sites 4, 21, and 22. Note that the discussion focuses on organic contamination. Inorganic constituents were detected in all the media sampled as part of the Round Two investigation. Based on a review/evaluation of the data, no trends or hot spots of inorganic contamination were identified. The detected inorganic concentrations will be evaluated in the human health and ecological risk assessments; however, the extent of inorganics in the various site media will not be presented in the following subsections.

4.3.1 Site 4

4.3.1.1 Surface and Subsurface Soil

The following subsections discuss the extent of soil contamination at Site 4. The discussion of surface water and sediment in this section is representative of all the sites.

Surface Soil

Low concentrations of VOCs were detected sporadically and generally at low frequencies. Most of the detections (methylene chloride, acetone, 2-butanone) could be associated with common

laboratory contaminants. The low levels of trichloroethene and toluene may be contributed to past disposal practices.

Following evaluation of data collected during the Round Two RI, concentrations of SVOCs which were identified as soil contaminants across the site are consistent with the analytical results from the Round One sampling event. The concentrations of SVOCs (mainly PAHs) were generally spread throughout the landfill. Elevated levels of PAHs detected within four adjacent sample locations defined a hot spot located in the southwest portion of the site. The SVOCs detected were possibly related to past disposal practices (disposal of asphalt, roofing tar, utility poles, and miscellaneous construction material).

Low concentrations of detected pesticides were consistent with historical Station-wide spraying. The low levels of PCB compounds were detected in surface soils within the same area as they were detected in the Round One RI (along the gravel road traversing through the site). Like the pesticide compounds the PCB detections may be attributed to the application of oil to suppress the dust on the roadways.

Explosives were detected within the surface soil at the northeast portion of the site. The detection of these compounds was isolated and may be indicative of past disposal practices. These compounds were detected downgradient from where similar compounds were detected in the Round One RI (the soil in this area was removed by IT Corp.)

Most of the inorganics (19 of 20) were detected within the surface soil samples. The majority of them were sporadic and at low frequencies. Concentrations of arsenic, beryllium, iron, and zinc were detected at a greater rate. These inorganics may be attributed to past disposal practices.

Overland transport of contaminated soils by runoff flowing toward Site 22 and to the unnamed tributary to the east branch of Felgates Creek is a potential pathway for surface soil contaminant migration. Analytical results from surface water/sediment samples collected in the unnamed tributary indicate that the surface soil contaminants (explosives) detected at Site 4 may have migrated to or had an impact on this surface water body.

The surface soil at Site 4 (with the exception of the AOC) has not been significantly impacted by site operations. There is no apparent source or discernible pattern of contamination within this media.

Subsurface Soil

Results of the subsurface soil investigation at Site 4 indicate that low levels of one VOC, toluene; one SVOC, bis(2-ethylhexyl)phthalate; and two pesticide compounds, 4,4-DDT and methoxychlor were detected at low frequencies. Due to the low concentrations and the sporadic appearances at the site, these compounds do not appear to be associated with the past disposal practices at the site.

Inorganics detected within the subsurface soil were similar to inorganics detected within the surface soil. The relatively low concentrations were within the Station-wide background levels.

The subsurface soil at Site 4 has not been significantly impacted by site operations. There is no apparent source or discernable pattern of contamination within this media. The leaching of subsurface soil contaminants to groundwater is a potential contaminant migration pathway. Organic contaminants detected in groundwater at Site 4 have likely migrated through (or from) the subsurface soil. However, the analytical results from the subsurface soil samples collected during this investigation indicate that this media is not currently acting as a source of groundwater degradation at Site 4.

4.3.1.2 Groundwater

This section addresses the extent of groundwater contamination at Site 4. Figure 4-6 illustrates the extent of organic contaminants in groundwater. Possible sources of groundwater contamination and potential migration of contamination are also evaluated.

During the Round Two RI shallow and deep monitoring wells were installed within the shallow and deeper Yorktown-Eastover aquifer at Site 4 to determine the horizontal and vertical extent of groundwater contamination.

Results of the Round Two RI indicated that the horizontal extent of VOC and nitramine contamination (chlorinated solvents and explosives) detected in the Round One RI at Site 4 is limited to the southern portion of the landfill adjacent to Site 22. The highest concentrations of TCE were detected at 4GW05 and 4GW04 at 91 µg/L. TCE were not detected at depth within monitoring wells 4GW06A (65-ft depth) and 4GW02A (80.5-ft depth). Nitramine compounds, RDX, 2,4/2,6-dinitrotoluene, 2,4,6-trinitrotoluene, and amino-DNTs, were also detected within the shallow portion of the aquifer at relatively low concentrations and at low frequencies. These compounds were not detected at greater depths within the aquifer. The VOC and nitramine compounds detected at the site may be attributed to past site operations. Pesticide compounds were detected well below the Federal MCLs and the Commonwealth of Virginia PMCLs. However, these results may not be accurate. Pesticides were detected in the deep monitoring well 4GW06A and not in the immediately adjacent, shallow well, which would be expected if the results reflected actual conditions.

Concentrations of inorganics in shallow groundwater were generally within the range of the Station-wide levels for both total and dissolved fractions (with the exception of manganese which exceeded the Federal MCLs for both the total and dissolved fractions).

The vertical extent of groundwater contamination appears to be limited to the shallow portion of the Yorktown-Eastover aquifer. Groundwater flow at Site 4 is generally toward the south (Site 22). The horizontal extent of groundwater contamination is limited to a southern area adjacent to Site 22.

4.3.1.3 Surface Water

The Round Two RI surface water analytical results were consistent with the Round One RI results; VOCs, SVOCs, and pesticides/PBS were not detected in the surface water. Nitramine compounds were detected within the unnamed tributary to the east branch of Felgates Creek. Generally, more compounds were detected upstream at greater concentrations. In addition, nitramine compounds were detected in surface soil samples at the eastern portion of Site 4, which may indicate migration of surface soil contaminants to the surface water.

The inorganic concentrations detected within the surface water were generally within the range of Station-wide background levels.

4.3.1.4 Sediment

Relatively low concentrations of VOCs, SVOCs, nitramine and pesticide compounds were detected within the sediment samples. These concentrations may be associated with residual contaminant migration from Site 4.

The concentrations of inorganics detected within the samples were generally within the range of Station-wide background levels.

The sediment within the study area has not been significantly impacted by operations at Sites 4, 21, and 22.

4.3.2 **Site 21**

4.3.2.1 Surface and Subsurface Soil

The following subsections discuss the extent of soil contamination at Site 21.

Surface Soil

Low concentrations of VOCs were detected sporadically and generally at low frequencies. Most of the detections (methylene chloride, acetone,) could be associated with common laboratory contaminants. The low levels of toluene may be contributed to past disposal practices.

Low concentrations of SVOCs (mainly PAHs) were generally spread throughout the site and did not exhibit a pattern.

Low concentrations of pesticides that were detected are consistent with historic Station-wide spraying.

Most of the inorganics (19 of 20) were detected within the surface soil samples at relatively low concentrations. These inorganics may be attributed to past disposal practices of batteries, scrap metal, and construction debris.

Overland transport of contaminated soils by runoff flowing toward the unnamed tributary to the east branch of Felgates Creek is a potential pathway for surface soil contaminant migration. Analytical results from surface water/sediment samples collected in the unnamed tributary indicate that the surface soil contaminants detected at Site 21 have not had an impact on this surface water body.

The surface soil at Site 21 has not been significantly impacted by site operations. There is no apparent source or discernible pattern of contamination within this media.

Subsurface Soil

Results of the subsurface soil investigation at Site 21 indicate low levels of VOCs (acetone, methylene chloride, and toluene). These compounds do not appear to be the result of past disposal activities. In addition, methylene chloride and acetone are common laboratory contaminants.

Low concentrations of SVOCs were detected sporadically throughout the site. These SVOC compounds do not appear to be associated with the site.

Five pesticide compounds (4,4-DDT, 4,4-DDE, 4,4-DDD, alpha-chlordane, gamma-chlordane, and methoxychlor) were detected at low concentrations and at low frequencies. The low concentrations and sporadic distribution at the site indicate that these compounds are not associated with the past disposal practices at the site.

Inorganics detected within the subsurface soil were similar to inorganics detected within the surface soils. The relatively low concentrations were within the Station-wide background levels.

The subsurface soil at Site 21 has not been significantly impacted by site operations. There is no apparent source or discernable pattern of contamination within this media. The leaching of subsurface soil contaminants to groundwater is a potential contaminant migration pathway. Organic contaminants detected in groundwater at Site 21 have likely migrated through (or from) the subsurface soils. However, the analytical results from the subsurface soil samples collected during this investigation indicate that this medium is not currently acting as a source of groundwater degradation at Site 21.

4.3.2.2 Groundwater

This section addresses the extent of groundwater contamination at Site 21. Figure 4-6 illustrates the extent of organic contaminants in groundwater. Possible sources of groundwater contamination and potential migration of contamination are also evaluated.

Results of the Round Two RI indicated that low levels of VOCs were detected in two monitoring wells at Site 21. The concentrations detected were below the Federal MCLs and the Commonwealth of Virginia PMCLs. Although past sampling events did not detect these VOCs, empty cans of solvents were discovered during reconnaissance of the site (Baker, 1996).

Concentrations of inorganics in shallow groundwater were generally within the range of the Station-wide levels for both total and dissolved fractions, with the exception of manganese and zinc, which may be related to the batteries that were disposed at the site.

The contaminants detected in groundwater at Site 21 are sporadic and at low concentrations. Groundwater flow at Site 21 is generally toward the unnamed tributary that flows to Felgates Creek. It does not appear that past site operations have had an adverse impact the groundwater at the site.

4.3.3 **Site 22**

4.3.3.1 Surface and Subsurface Soil

The following subsections discuss the extent of contamination at Site 22.

Surface Soil

Low concentrations of SVOCs (mainly PAHs) are generally spread throughout the site. The SVOCs detected are possibly related to past site activities of burning solvents and explosives.

Low concentrations of pesticides which were detected are consistent with historical Station-wide spraying.

Low concentrations of explosives were detected within surface soil samples at the site. The detection of these compounds was isolated and may be indicative of past site activities.

Most of the inorganics (19 of 20) were detected within the surface soil samples. The majority of them were sporadic and at low frequencies. Concentrations of arsenic, beryllium, cadmium, copper, iron, lead and manganese were detected at higher concentrations. These inorganics may be attributed to past site activities.

Overland transport of contaminated soils by runoff flowing toward the east branch of Felgates Creek 22 is a potential pathway for surface soil contaminant migration. Analytical results from surface water/sediment samples collected in Felgates Creek do not indicate adverse effects from contaminant migration from surface soil.

The surface soil at Site 22 has not been significantly impacted by site operations.

Subsurface Soil

Results of the subsurface soil investigation at Site 22 indicate that low levels of VOCs, acetone, carbon disulfide, and toluene; one SVOC, Bis[2-ethyl hexyl]phthalate; nitramines; and pesticide compounds were detected at low concentrations and at low frequencies.

Inorganics detected within the subsurface were similar to inorganics detected within the surface soil. The relatively low concentrations were within the Station-wide background levels.

The subsurface soil at Site 22 has not been significantly impacted by site operations. There is no apparent source or discernable pattern of contamination within this media. The leaching of subsurface soil contaminants to groundwater is a potential contaminant migration pathway. Organic contaminants detected in groundwater at Site 22 have likely migrated through (or from) the subsurface soils. However, the analytical results from the subsurface soil samples collected during this investigation indicate that this medium is not currently acting as a source of groundwater degradation at Site 22.

4.3.3.2 Groundwater

This section addresses the extent of groundwater contamination at Site 22. Figure 4-6 illustrates the extent of organic contaminants in groundwater. Possible sources of groundwater contamination and potential migration of contamination are also evaluated.

During the Round Two RI, shallow and deep monitoring wells were installed within the shallow and deeper (Yorktown-Eastover) aquifers at Site 22 to determine the horizontal and vertical extent of groundwater contamination.

Results of the Round Two RI indicated that the horizontal extent of VOC and nitramine contamination (chlorinated solvents and explosives) detected at Site 22 was most prevalent in the southern half of the site. The highest concentration of TCE was detected at 22GW04 at 1,200 µg/L. This well also had the highest concentrations of RDX at 110 µg/L. This well is located adjacent to the burn area. The VOC and nitramine compounds detected at the site appear to be attributed to past site operations. Detections of similar compounds were observed within the samples collected from monitoring wells 22GW01 and 22GW01A at lower (one order of magnitude) concentrations.

Concentrations of inorganics in shallow groundwater were generally within the range of the Station-wide levels for both total and dissolved fractions, with the exception of iron and manganese which exceeded the Federal MCLs for both the total and dissolved fractions.

The vertical extent of groundwater contamination appears to be limited to the shallow portion of the Yorktown-Eastover aquifer. The concentrations detected in the deeper (55-ft bgs) portion of the aquifer are generally one order of magnitude lower. Groundwater flow at Site 22 is toward the east branch of Felgates Creek. Surface water and sediment samples collected downgradient of Site 22 do not exhibit VOC contamination. The groundwater at Site 22 does not appear to adversely impact the surface water and sediment within Felgates Creek.

4.3.3.3 Sediment

Relatively low concentrations of VOCs, SVOCs, nitramine and pesticide compounds were detected within the sediment samples collected within the marsh area at the southern portion of Site 22. These may be associated with residual contaminant migration from Site 22.

The concentrations of inorganics were detected within the samples were generally within the range of Station-wide background levels.

The sediment within the study area has not been significantly impacted by operations at Site 22.

4.4 References

Baker Environmental, Inc. 1995. Summary of Background Constituent Concentrations and Characterization of the Biotic Community from the York River Drainage Basin, Naval Weapons Station Yorktown, Yorktown, Virginia Final. April, 1995.

Long, Edward R., Donald D. MacDonald, Sherri L. Smith, and Fred D. Calder. 1995. "Incidence of Adverse Biological Effects Within Ranges of Chemical Concentrations in Marine and Estuarine Sediment," Environmental Management, Vol. 19, No. 1, PP. 81-97. Springer-Verland New York Inc.

United States Environmental Protection Agency. 1997a. "Risk-Based Concentration Summary Table." March 17, 1997. Region III, Philadelphia, Pennsylvania.

United States Environmental Protection Agency. 1989. Risk Assessment Guidance for Superfund Volume I. Human Health Evaluation Manual (Part A) Interim Final. Office of Solid Waste and Emergency Response. Washington, D.C. December 1989. EPA/540/1-89-002.

TABLE 4-42

SURFACE SOIL-POSITIVE DETECTION SUMMARY
DIOXIN COMPOUNDS
SITES 4, 21, AND 22, CTO-349
NAVAL WEAPON STATION YORKTOWN, YORKTOWN, VA

SAMPLE ID	4SS01A	4SS01B	21SS01A	21SS01B	22SS01A	22SS01B	22SS01C	22SS01D	
SAMPLE DATE	6/15/00	6/15/00	6/15/00	6/15/00	6/15/00	6/15/00	6/15/00	6/15/00	
DEPTH (INCHES)	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	
TEQ (Min.-Max.)	pg/g	4.47 - 4.72	9.09 - 9.09	4.48 - 4.49	2.97 - 2.97	6.56 - 6.67	21.2 - 21.3	8.84 - 9.07	1.05 - 1.20

NOTES:

(1) Background samples collected throughout Weapon Station

(2) TEQ - Toxicity equivalent is the product of the concentration, C_i , of an individual "dioxin-like compound"

in a complex environmental mixture and the TCDD toxicity equivalent factor (TEFi) for that compound.

pg/g - picogram per gram; parts per trillion

TABLE 4-42

SURFACE SOIL-POSITIVE DETECTION SUMMARY
DIOXIN COMPOUNDS
SITES 4, 21, AND 22, CTO-349
NAVAL WEAPON STATION YORKTOWN, YORKTOWN, VA

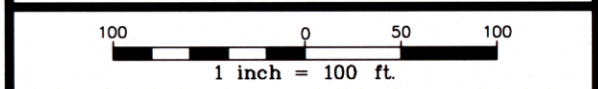
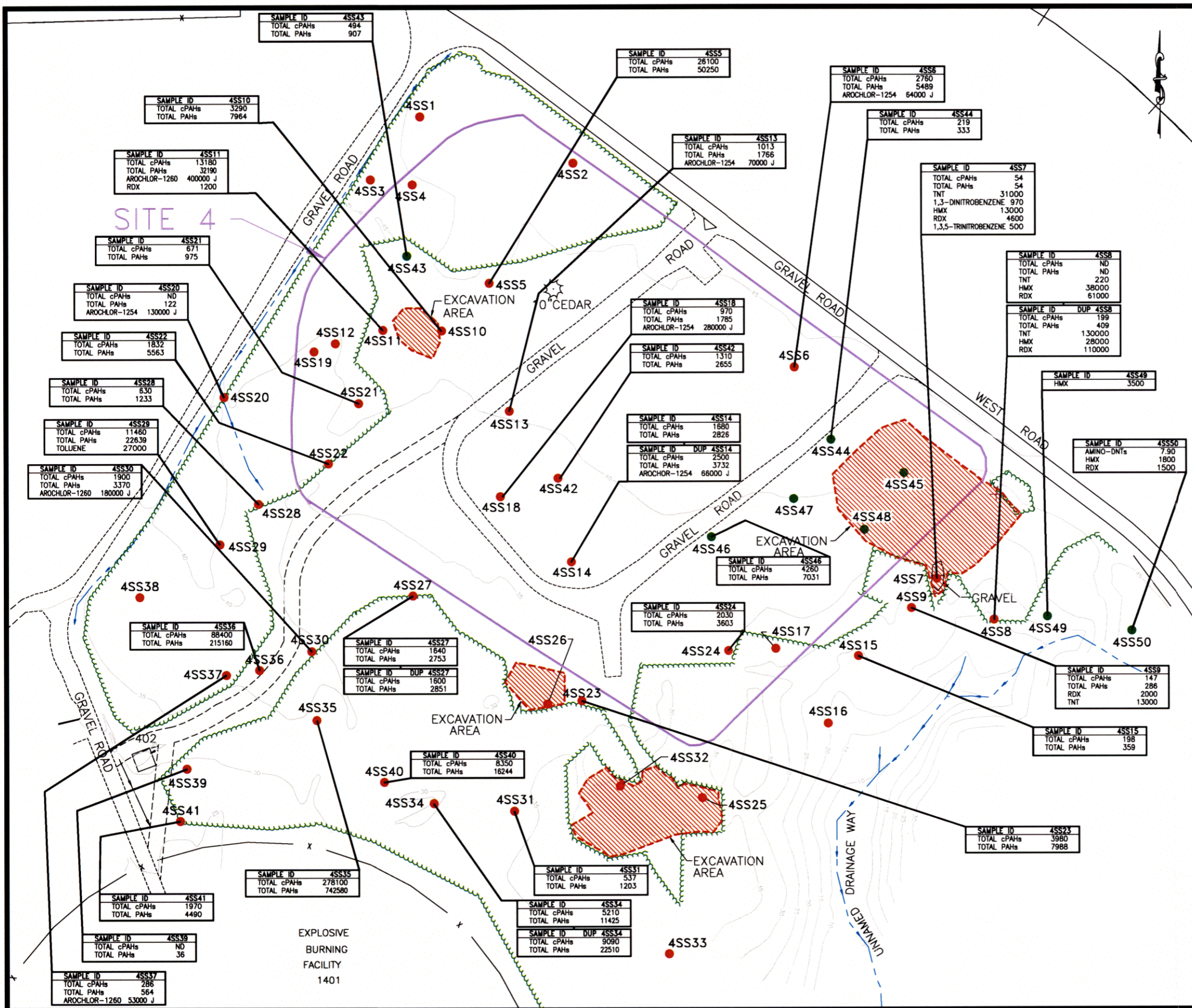
SAMPLE ID	BGS31	BGS10	BGS05	BGS41	BGS19
SAMPLE DATE	6/14/00	6/14/00	6/14/00	6/14/00	6/14/00
DEPTH (INCHES)	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6
TEQ (Min.-Max.) pg/g	2.08 - 2.21	1.22 - 1.39	1.91 - 2.11	1.17 - 1.42	10.9 - 11.3

NOTES:

(1) Background samples collected throughout Weapon Station

(2) TEQ - Toxicity equivalent is the product of the concentration, C_i , of an individual "dioxin-like compound"

in a complex environmental mixture and the TCDD toxicity equivalent factor (TEFi) for that compound.
pg/g - picogram per gram; parts per trillion



- DRAINAGE
- MARSH
- RAILROAD
- FENCE
- TREE LINE
- EDGE OF PAVEMENT
- STRUCTURE
- APPROXIMATE SITE BOUNDARY
- EXCAVATION AREA

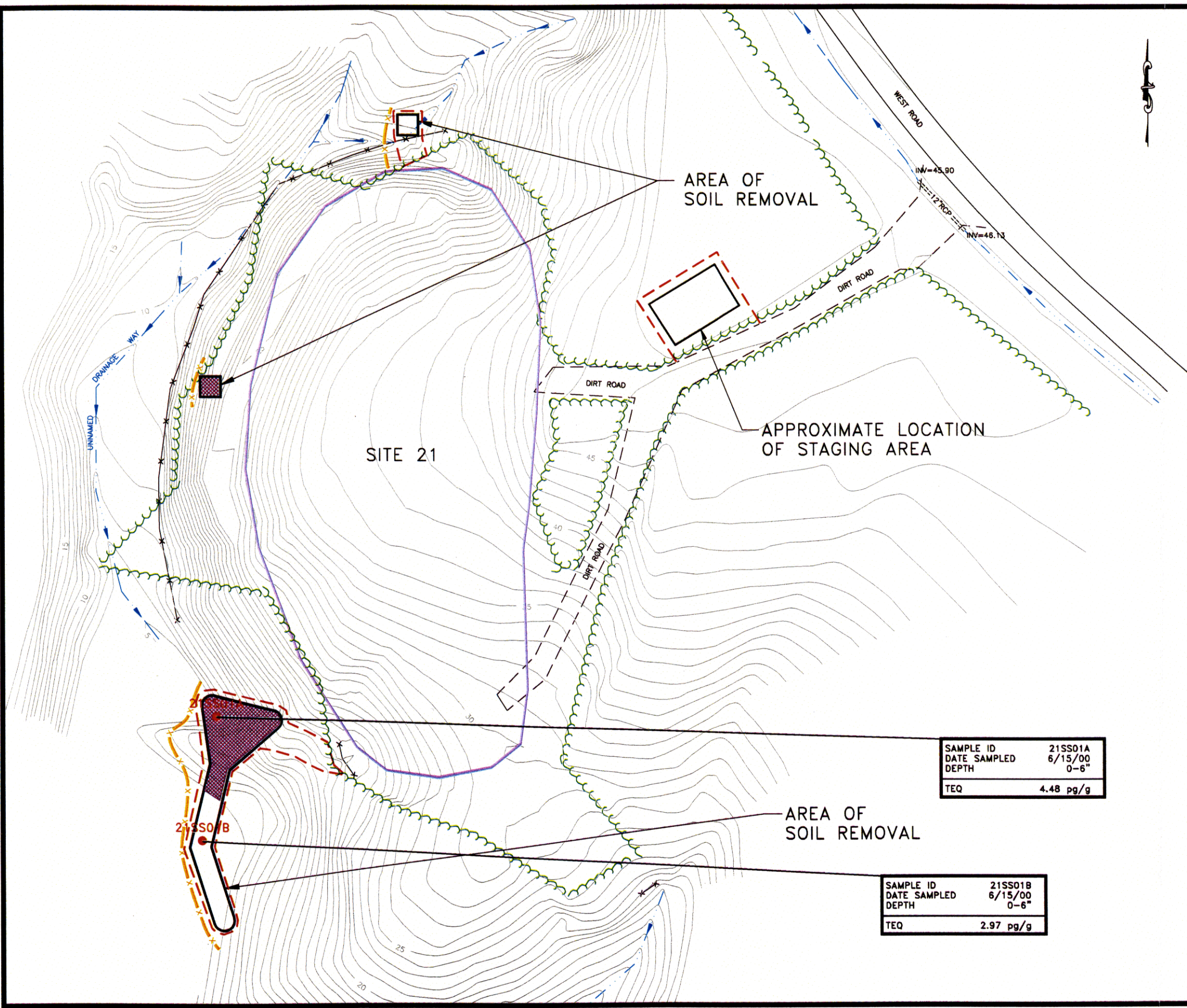
4SS1-4SS42 SURFACE SOIL SAMPLE LOCATION
REMOVAL ACTION (SAMPLED JUNE 1994)

4SS43-4SS50 ROUND TWO SURFACE SOIL
SAMPLE LOCATION (SAMPLED OCTOBER 1996)

---25---
CONTOUR LINE WITH
ELEVATION, MSL

ug/kg - MICROGRAMS PER KILOGRAM
cPAH - CARCINOGENIC PAH
PAH - POLYNUCLEAR AROMATIC HYDROCARBON
TNT - 2,4,6-TRINITROTOLUENE
CONCENTRATIONS ARE PRESENTED IN ug/kg.

**FIGURE 4-2
POSITIVE DETECTIONS OF
SELECT ORGANIC COMPOUNDS
IN SURFACE SOIL
SITE 4**



SAMPLE ID	21SS01A
DATE SAMPLED	6/15/00
DEPTH	0-6"
TEQ	4.48 pg/g

SAMPLE ID	21SS01B
DATE SAMPLED	6/15/00
DEPTH	0-6"
TEQ	2.97 pg/g

NAVAL WEAPONS STATION YORKTOWN

Baker Environmental, Inc.

50 0 25 50

1 inch = 50 ft.

LEGEND

- SURFACE SOIL SAMPLE LOCATION
- EDGE OF PAVEMENT
- x x FENCE
- ~ EDGE OF WOODS
- DRAINAGE DITCH
- CONTOUR LINE
- REMEDIAL INVESTIGATION SITE
- AREA TO HAVE IN-SITU SOLIDIFICATION/STABILIZATION
- EXTENT OF CLEARING AND GRUBBING
- x x SILT FENCE
- EROSION MATTING

NOTES:

TEQ - TOXIC EQUIVALENT QUOTIENT BASED ON

- TOXIC EQUIVALENT QUOTIENT BASED ON

pg/g - PARTS PER TRILLION

FIGURE 4-23

RESULTS OF DIOXIN ANALYSIS

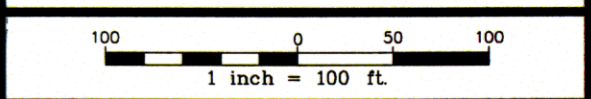
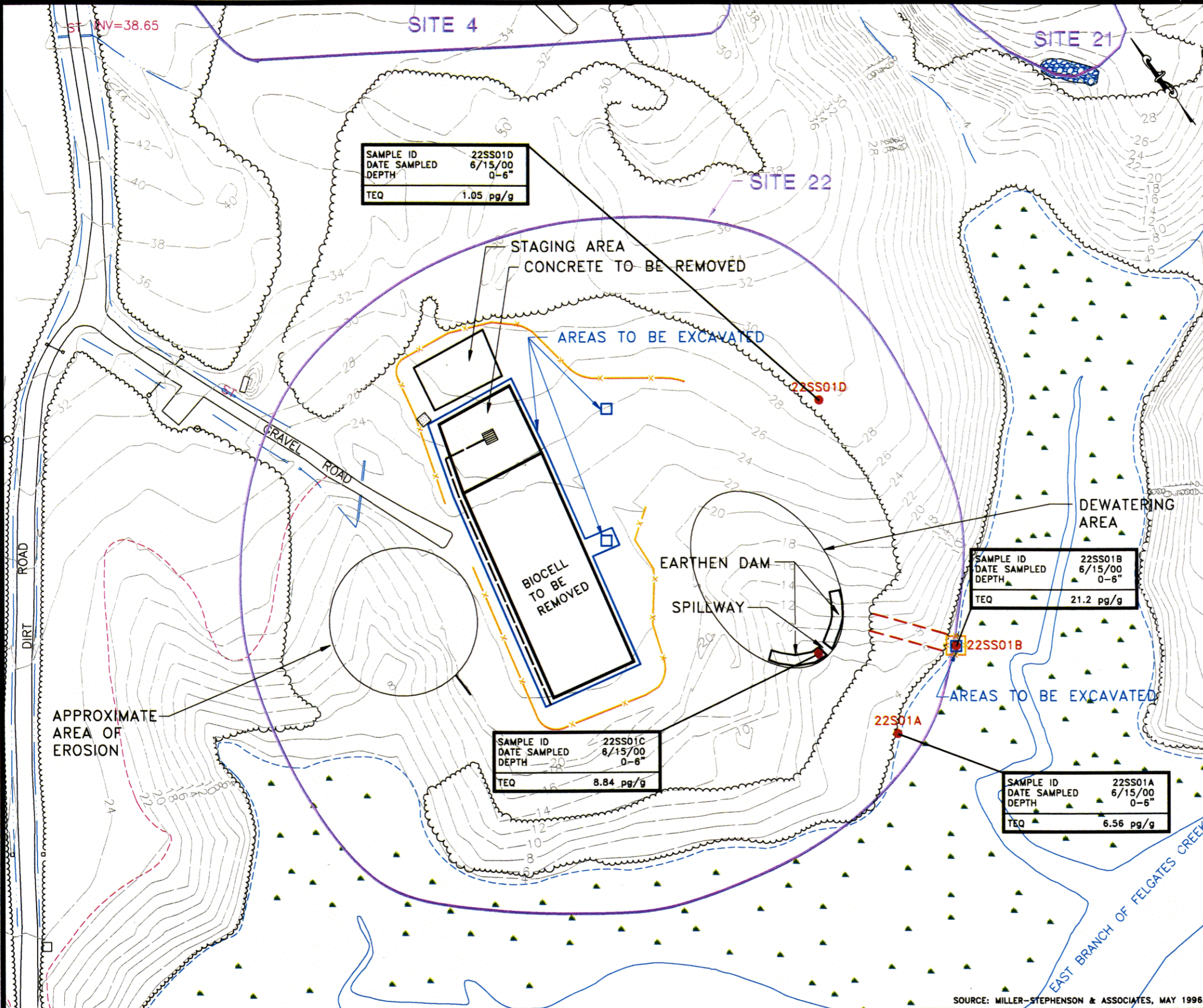
FOR SURFACE SOIL SAMPLES

SITE 21

ADJACENT TO SITE 4

CTO - 0394

NAVAL WEAPONS STATION YORKTOWN YORKTOWN, VIRGINIA



- DRAINAGE
- MARSH
- TREE LINE
- EDGE OF PAVEMENT
- STRUCTURE
- REMEDIAL INVESTIGATION SITE
- FRENCH DRAIN
- SURFACE SOIL SAMPLE LOCATION
- EXTENT OF CLEARING AND GRUBBING
- SILT FENCE
- AREA TO BE EXCAVATED FOR OFF-SITE DISPOSAL
- CONTOUR LINE WITH ELEVATION, MSL
- GRATE
- RIPRAP

NOTES:
TEQ - TOXIC EQUIVALENT QUOTIENT BASED
ON USEPA TOXIC EQUIVALENT FACTORS
pg/g - PARTS PER TRILLION

FIGURE 4-24
RESULTS OF DIOXIN ANALYSIS
SURFACE SOIL SAMPLES
SITE 22
CTO - 0394

NAVAL WEAPONS STATION YORKTOWN YORKTOWN, VIRGINIA



3000 0 1500 3000
1 inch = 3000 ft.

LEGEND

SSA IN PROGRESS	BUILDINGS	STATION BOUNDARY	
SITE IN PROGRESS	STRUCTURES	STATION BOUNDARY W/FENCE	
SSA COMPLETE	ROADS: PAVED	MARSH, SWAMP	
SITE COMPLETE	ROADS: UNPAVED	GATE	
	TRACK/TRAIL	FENCES	
	RAILROADS	WALLS	
		TRANSFORMER	

NOTES:
TEQ - TOXIC EQUIVALENT QUOTIENT BASED ON USEPA TOXIC EQUIVALENT FACTORS
pg/g - PARTS PER TRILLION

SOURCE OF BASE MAPPING: LANTDIV, 1995.

FIGURE 4-25
RESULT OF DIOXIN ANALYSIS
FOR BACKGROUND
SURFACE SOIL SAMPLES
CTO - 0394

NAVAL WEAPONS STATION YORKTOWN YORKTOWN, VIRGINIA

Baker
Baker Environmental, Inc.